NASA CONTRACTOR REPORT 166514

Integrated Resource Inventory for Southcentral Alaska (INTRISCA) Final Report

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ABSTRACT

The Integrated Resource Inventory for Southcentral Alaska (INTRISCA) Project comprised an integrated set of activities related to the land use planning and resource management requirements of the participating agencies within the southcentral region of Alaska. One subproject involved generating a region-wide land cover inventory of use to all participating agencies. Toward this end, participants first obtained a broad overview of the entire region and identified reasonable expectations of a Landsat-based land cover inventory through evaluation of an earlier classification generated during the Alaska Water Level B Study. Classification of more recent Landsat data was then undertaken by INTRISCA participants. The latter classification produced a land cover data set that was more specifically related to individual agency needs, concurrently providing a comprehensive training experience for Alaska agency personnel. Other subprojects employed multi-level analysis techniques ranging from refinement of the region-wide classification and photointerpretation, to digital edge enhancement and integration of land cover data into a geographic information system (GIS).

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CHAPTER I
INTRODUCTION

SCOPE OF THE FINAL REPORT

This report documents the efforts and accomplishments of the INTRISCA project and participating team members from its inception through its completion. The focus will be threefold: how the project team conducted its investigation and met the project objectives, what conclusions evolved from the investigations, and how the technical aspects of the project were carried out. In addition to documenting INTRISCA ativities, it is hoped that this report may assist future users and technical support staff in accomplishing their own projects more expeditiously while avoiding difficulties encountered by the project team. Finally, it is hoped that this document will assist decision makers and administrators in assessing the role remote sensing might play in an operational mode within their own agencies.

The report is divided into two primary sections. The appendices contain the technical papers which describe the technical processes and analyses conducted for the project. Chapters I through VI are intended to provide a brief non-technical overview of the demonstration project.

BACKGROUND: The Integrated Resource Inventory for Southcentral Alaska (INTRISCA)

A cooperative project has been undertaken by the National Aeronautics and Space Administration (NASA) and various state and local government agencies in southcentral Alaska. The Alaska State and Local Remote Sensing Demonstration Program is an Applications Systems Verification and Transfer (ASVT) project. This demonstration project employed the technical capabilities of the NASA AMES RESEARCH CENTER to demonstrate to potential users from state and local government agencies in southcentral Alaska, the utility of Landsat derived information in land use planning and in the management of natural resources. The goal of the demonstration project was to provide users with hands-on experience and training in the actual extraction, manipulation, and evaluation of remotely sensed data.

The main objective of the INTRISCA project was to provide various user groups with uniform data sets (standard land cover classifications, plotter maps, Dicomed prints and statistical summaries) on land use and land cover derived from Landsat imagery and high altitude aircraft photography. The INTRISCA project has provided for user evaluation, user training, and critique of land use/land cover information derived from the demonstration project.

State and local agencies are faced with a continuing need for obtaining and keeping current land cover/land use and natural resource information. Alaska has over 47,000 miles of coastline but 1/5 of 1 percent of the total coastal area supports 60% of the entire state population. The demonstration project concentrated on this area of Southcentral Alaska.

NASA'S ROLE

NASA's Regional Remote Sensing Program is designed to facilitate user assessment and adoption of Landsat technology by providing assistance primarily to state and local governments. The program includes:

- A liaison and awareness effort, which seeks to acquaint prospective users with the many opportunities for using remotely sensed data. Several briefings and meetings were held in Anchorage to acquaint agency personnel with such opportunities and programs. As a result of these early meetings in 1979, the INTRISCA project and project team was established.

- NASA-provided orientation and training in techniques of analyzing remotely sensed data. All participating agencies have now received several hands-on training workshops in both aerial photographic interpretation and digital analysis.

- Cooperative user/NASA demonstration projects (such as INTRISCA) are conducted to show Landsat's capability as a land use and resource management tool.

- Technical assistance to help user agencies locate sources of services and systems, to help them apply the technology to their own projects, and to keep them informed on advances in technology. The INTRISCA project had many common goals and projects, but also provided for specific agency subprojects. This allowed various agencies to apply remote sensing technology to their own specific in-house projects.

The Regional Remote Sensing Applications Program is concentrated at three NASA field installations, each covering a specific geographical area of the United States. Ames Research Center, located at Moffett Field, California serves the western states, including Alaska and Hawaii through its Western Regional Applications Program (WRAP). The prime objectives of WRAP are:

1. to provide an opportunity for state and local government agencies to test and evaluate remote sensing technology,

2. assist user agencies in its transition to operational use, and

3. transfer high technlogy to these groups.

The INTRISCA project is the result of such an effort by NASA. The following table illustrates NASA's role and the role the participating agencies are expected to take since such demonstration projects are user driven and are based on active agency participation.

NASA'S ROLE

- Information and Training
- Demonstration Project Support
- Image Analysis Processing
- User Needs Survey Assistance
- Definition of Operational Alternatives
- Assistance in the Use of Future Satellite Data

USERS' ROLE

- State Coordinating Functions
- Identification of Applications Problems
- Active Participation
- Commitment of Personnel and Fiscal Resources
- Technology Evaluation
- Sharing of Project Experiences with others.

THE NEEDS AND MANDATES FOR THE DEMONSTRATION PROJECT

Southcentral Alaska is experiencing rapid growth and development, and much of the land area is inaccessible by conventional ground transportation means. For example, the Municpality of Anchorage covers approximately 2,000 square miles but only 15 percent of the area is accessible by road. The Matanuska-Susitna Borough, north of Anchorage, contains 23,000 square miles and less than 1 percent of it is accessible by road. Within the boundaries of these two local governments numerous potentials exist for the development of natural resources. Large coal deposits, lands suitable and planned for agricultural development, commercial forestry potential, critical wildlife habitat, and lands suitable for residential, commercial and industrial

development are present throughout the region. However, the natural resources of the area have not previously been completely inventoried or mapped. A need existed to inventory, classify and map the land use and land cover so that it could be used in the preparation of land use and resource management plans necessary before such development proceeds.

LEGISLATIVE MANDATES

The State of Alaska is unique in that recent and impending legislative mandates require the transfer of millions of acres of federal, state, local and native-selected lands. Land transfer requirements of these Acts dictate statewide land inventory and use-classification, now largely non-existent in Alaska. To address these critical inventory needs, the Alaska ASVT was designed to demonstrate and transfer methods for regional land inventory based on Landsat digital data and U-2 high altitude photography. A detailed description of major land transfer mandates follows as stated in an Alaska Department of Natural Resources document[1]. As of December, 1978, land ownership was distributed as follows:

Private (Non-Native)	01.0%
Native Corporations	12.0%
State government	27.0%
Federal government	60.0%

The effect of federal policies and actions is most clearly demonstrated by the pattern of land ownership that existed when the Statehood Act was passed in 1958. In that year, 99.8 percent of the land was still owned by the federal government. The Statehood Act, passed in 1958, marked the beginning of dramatic shifting in these land ownership patterns. First, it entitled the State to select a total of 103.35 of the 367 million acres of land in Alaska. These selections were to be of two kinds. The first, general land grants, entitled the state to select up to 102.55 million acres of unreserved federal land by January, 1984. The second, community land grants, allowed the state to select 400,000 acres from the national forests and another 400,000 from the public domain lands to meet community needs.

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[1]Source: Department of Natural Resources, Division of Forest, Land and Water Management, "Land for Alaskans", 1978.

In passing the Statehood Act, Congress cited economic independence and the need to open Alaska to economic development as the primary purposes for large Alaska land grants. The Alaska Constitution, on the other hand, speaks of both conservation and development as key factors in managing and disposing of land, with the dominant theme being development.

The state's initial land selections were small and carefully calculated, largely due to the young state's precarious financial position. The State simply could not afford to select the whole 103.35 million acres. By 1968, the State had selected about 26 million acres of its statehood entitlement. Most of these lands were chosen for their immediate potential to bolster the Alaska economy and their proximity to existing transportation routes.

Native leaders, first prompted by the State selections of Native hunting grounds near Minto in the mid-1960's, asserted Native claims to large areas of the state. Acting to protect Native land rights, Secretary of the Interior Stuart Udall froze "final action" on federal land transaction (including State selections) in 1966. In 1968, oil was discovered on the North Sope and the need for an oil pipeline right-of-way provided impetus for the settlement of Native Claims. The issue of Native claims in Alaska was cleared with passage of the Alaska Native Claims Settlement ACT (ANCSA) on December 18, 1971. This Act, the result of a tremendous struggle by Natives and their supporters, created Alaska Native village and regional corporations and gave them nearly one billion dollars and the right to select 44 million acres of land. The land selected, as defined by the Act, is mainly in the vicinity of Native villages, which are largely located along major rivers or on the coast. However, in the demonstration study area several hundred thousand acres have been transferred to Native Village Corporations and Regional Corporations.

Section 17 (d)(2) of the Settlement Act allowed the Secretary of the Interior to withdraw up to 80 million acres for further study leading to classification as national parks, wildlife refuges, forests, and wild and scenic rivers. The Act also directed the withdrawal of substantial areas (ultimately totaling some 116 million acres) to form a pool from which the Natives were to chose their lands.

A month after the passage of the Settlement Act, the State filed selections of some 77 million acres of land before the creation of the Native and federal pools. The Department of the Interior refused to allow these selections, and, in September, 1972, the litigation initiated by the State was resolved by a settlement affirming state selection of 41 million acres. The State's next selection in 1973-4 was 2.5 million acres, primarily selected for mineral potential.

After the expiration of some Native selection rights in late 1976, the state selected 3.6 million acres, following an extensive evaluation and public review process.

The completion of state land selections was blocked until Congress acted to resolve the (d)(2) issue; to decide which of the withdrawn lands would be put into federal management systems. In order to protect the states interests, in May, 1978, after widespread public review, Alaska identified 41 million acres of "state interest areas," and requested that they be conveyed to the state by Congress as part of the final (d)(2) legislation.

Of the 220 million acres which the federal government was likely to retain in Alaska, about 72 million acres have already been designated as National Forest, National Parks, Wildlife Refuges, and Petroleum Reserves.

In December of 1980 President Carter signed The Alaska Lands Bill settling the (d)(2) issue.

Territorial trust grants plus the generous statehood grants will see the State of Alaska with title to 104.55 million acres, an area larger than the State of California. Although the State has selected over 72 million acres of its statehood entitlement, only 21 million acres have been patented (final title) by the federal government. These patented lands, plus the 15 million acres which have been tentatively approved for patent, comprise the 36 million acres which the State now manages (and may offer under disposal programs).

In 1963, the Legislature passed the Mandatory Borough Act, with the intention of granting land to the municipalities for the same reason land was given to the State upon statehood--to establish an economic base. The Act allowed municipalities to select ten percent of the vacant and unappropriate state general grant land within their boundaries. Dispute over the handling of these lands led to litigation, which was settled by an act passed in 1978 that allocated 860,000 acres to the existing eleven boroughs.

Private land in Alaska, excluding land held by Native corporations, is estimated to be over one million acres. Much of this land passed into private hands through the federal homestead acts and the land disposal programs of the state, boroughs or communities.

Most private land is located along Alaska's road network. Compared to other categories of land it is highly accessible and constitutes some of the prime settlement land in the state.

The present state policy of Alaskan land management is found

in Chapter 181, SLA 1978, the culmination of an effort by Governor Jay S. Hammond, the Legislature and the Federal-State Land Use Planning Commission. The provisions of this Act were signed into law July 18, 1978. To implement the Act the Division of Lands must inventory all state land and water, and identify and classify their resources and other values. These inventories, which are to be kept up to date, are to be used to develop regional or area land use plans which will guide the management of State-owned lands.

To meet the goal of putting State land into private hands, the Act ordered the Division of Lands to designate by Nov. 1, 1978 30,000 acres of State land for disposal under either the homesite or open-to-entry programs. This land was part of the 50,000 acres which was to be made available during fiscal year 1979 (July 1, 1978 to July 1, 1979). After this first year, the Legislature will annually decide on the amount of land to be offered.

This State land policy is reflected in the land classification system, which is the step following the inventory and land planning process. Upon selection by the State, land is inventoried for its resources, and a land management plan is prepared. The plan then recommends classification of the land into one of the existing 16 classification categories. There are currently eight retention categories. They are: Watershed, Public Recreation, Reserved Use, Grazing, Material, Mineral, Timber and Resource Management. All of these are multiple-use categories which allow both dominant and nonconflicting uses. There are also eight disposal categories. They are: Homesite, Agricultural, Commercial, Industrial, Private Recreation, Residential, Utility and Open to Entry. Land will be selected for future disposal programs from these categories.

The Homesite Program was enacted by the Legislature in 1977 and amended in 1978. The program allows residents of the state who have lived in Alaska three years or longer to secure title to parcels up to five acres in size. The Legislature has directed that 30,000 acres of State land be designated for disposal in fiscal year 1979 under a combination of Homesite Entry and Open-to-Entry programs.

In an effort to protect Alaska's limited agricultural land base, and to encourage the development of agriculture, the 1976 Legislature provided that 650,000 acres of land were to be designated for agricultural use by 1979. This land may be used only for agricultural purposes, and will be sold at fair market value at either public auction or by lottery. Ownership of 68,200 acres were transferred to private hands in 1978.

The State of Alaska passed the Alaska Coastal Management Act in 1977. The Alaska Coastal Management Act, like the

Federal Act, tries to balance human use of coastal resources while maintaining natural systems. Coastal management is a joint effort by local, state and federal government agencies and the private sector to manage coastal resources and promote their wise and balanced use. In Alaska, local governments have the responsibility of preparing coastal management plans. State standards and guidelines require both a thorough resource inventory and analysis.

These and other resource management programs have necessitated a need for more efficient means of conducting large-scale inventories. Table 1 summarizes these mandates.

ALASKA REMOTE SENSING SUBCOMMITTEE

For these reasons, the local governments of the Cook Inlet region, in cooperation with various state agencies, were committed to developing a remote sensing demonstration plan for an integrated resource inventory to meet their resource management objectives and information needs, and to cooperatively acquire the knowledge needed for the planning and management of their land and water resources. The most efficient and cost effective method for obtaining this information is the implementation of remote sensing techniques, as this method offers great flexibility in extending its applications to complex projects requiring analysis of various levels and intensities.

In consideration of this the Alaska Remote Sensing Subcommittee (composed of federal, state, and local government personnel) has entered into an agreement with the National Aeronautics and Space Administration (NASA) to formulate and evaluate plans and alternatives for the application of remotely sensed data in the planning and decision-making processes.

Because of the multi-jurisdictional operations and programs in southcentral Alaska, as well as this geographic area containing a majority of the state's population and associated problems resulting from it, it was deemed appropriate that the local government entities should lead the project. The local government entities are in many cases larger than some states, and planning is a mandatory power of first- and second-class boroughs and home-rule municipalities.

Several Congressional and legislative mandates have created other land programs which are causing the land ownership picture to change drastically in Alaska. The Alaska Native Claims Settlement Act, for example, is conveying title of certain lands to Alaska Native Corporations. These lands will no longer be in Federal ownership but, instead, be privately-owned lands subject to borough and municipal planning authority. The State of Alaska has passed legislation to transfer title of certain state lands to

TABLE 1

LEGISLATIVE MANDATES

Legislative Mandates	Responsibility	Actions required
Statehood Act	Department of Natural Resources	Selection of 103.35 million acres for development of an economic base.
Alaska Native Claims Settlement Act (ANCSA)	Native Corporations	Selection of 44 million acres
ANCSA	Department of Interior	Selection of 80 million acres for parkland development
Mandatory Borough Act	Municipal Boroughs	Selection of 860,000 acres for development of an economic base
Land Policy Act	Department of Natural Resources	Disposal of 98,200 acres (FY79) to private sector.
Homestead Entry Program		Disposal of 30,000 acres (FY79) for homesteads.
Agricultural Land Classification Act		Disposal of 68,200 acres (FY79) for agricultural development.
Alaska Coastal Management Act	Local governments	Resource inventory and assessment and analysis of wetlands, habitats, Hazardous areas, land cover, etc.
Municipal Entitlements Act	Local governments	Selection of 10% of state lands within local service area for urban expansion
• Matanuska-Susitna Borough		Selection of 50,000 acres
• Municipality of Anchorage		Selection of 15,000 acres plus $9 million
State Forest Practices Act	Department of Natural Resources	Inventory and assessment of forest lands within state jurisdiction

boroughs and municipalities. These lands will be patented to local governments. However, vast amounts of both Federal and State land remains. The management and use of these lands often depend upon the goals, needs, and desires of the local residents. A cooperative planning and management program is needed and it is anticipated that the southcentral area could be the catalyst for initiating such a program. Local governments feel that they should be the initiating entities of the program plan in order that their specific needs are recognized and incorporated into the program at the state level.

State resource management issues, mandated by both federal and state legislation, require identification of resource values, inventorying, classification, analysis and mapping of natural resources. Many of the State-owned land areas of interest are located within the two local government entities, thus creating a need for coordinated, cooperative planning and management.

In order to carry out these objectives and tasks, representatives of all participating agencies have formed an ad hoc committee on remote sensing. One member of the Ad Hoc Committee is also a member of the Alaska Remote Sensing Subcommittee and coordinates the activities and interests of local government. The Ad Hoc Committee's primary responsibility is to assess the potentials of remote sensing in southcentral Alaska. This assessment will be accomplished through the preparation and implementation of the demonstration plan and the evaluation of the technical and adminstrative results of utilizing the technology.

PROJECT OBJECTIVES

The following are the objectives adopted by the participating user agencies:

1. Assess the utility of remote sensing techniques to current and projected coastal and other land and water use management problems and needs.

2. Assess the utility of remote sensing techniques to determine and create urban and rural land use and land cover maps.

3. Train state and local personnel to analyze and utilize Landsat and other remote sensing data for land use and resource management planning.

4. Demonstrate the feasibility of using computer-aided analysis of Landsat data with other interpreted data to aggregate the land use and land cover information by various planning boundaries (e.g., traffic analysis zones, census tracts, river

basins, etc.) for tabular output. This objective may be partially met through cooperative agreements with other Federal agencies to pool resources and share output data.

5. Evaluate existing systems and processes for the manipulation of remotely sensed data and to incorporate the use of such systems and techniques into current and proposed land use and resource management programs.

6. Analyze the cost effectiveness of utilizing remote sensing as a tool compared to conventional means of acquiring, mapping and manipulating data.

7. Develop a horizontally and vertically integrated agency environment in order to provide the foundation for a comprehensive state-wide remote sensing program.

DEMONSTRATION PROJECT PARTICIPATING AGENCIES

The following federal, state and local agencies have actively participated in this demonstration project:

- Matanuska-Susitna Borough, Planning Department
- Municipality of Anchorage, Planning Department
- Alaska Department of Fish and Game
- Alaska Department of Natural Resources
  - Division of Forestry
  - Land and Resource Planning
- U.S. Department of Agriculture, Soil Conservation Service
- NASA/Ames Research Center, Technology Application Branch

CHAPTER II
PROJECT CONSIDERATIONS, ORGANIZATION AND PLANNING

APPROACH

In order to meet the program objectives as listed in Chapter I, two local governments, in cooperation with state agencies, have conducted demonstration subprojects in each borough and municipality. Each demonstration subproject involved the identification of user needs, identification and analysis of appropriate remotely sensed data and evaluation of the data with respect to all user requirements. Each demonstration task has provided for the practical requirements and commensurate application of current remote sensing techniques. Determination of the level of detail available through digital analysis of Landsat data has also been accomplished, as well as an analysis of the best methods applicable to individual local problems. Results of the demonstration subprojects will be used to formulate future program recommendations, advance project applications, and suggestions of the operational mechanism for implementing remote sensing techniques in future land use and resource management programs. Where possible, cooperative agreements have been and will be written, allowing the sharing of resources among several agencies.

PROJECT OVERVIEW

INTRISCA has been conceived as an integrated set of activities related to the land-use planning and resource management requirements of the participating agencies within the southcentral region of Alaska.

The first objective of all participants was to obtain a broad overview of the entire region such as that provided by a Landsat digital land cover inventory. This general inventory served three purposes: (1) It provided a source of data that supports regional land use planning functions of each agency; (2) it offered a basis for intergovernmental cooperation and horizontal data integration among the two contiguous local governments which occupy the study area, and (3) it provided a basis for vertical data integration in which both state and local agencies combine Landsat, aerial photography, ground truth, and other existing information in analyses that range from large-area (borough-wide) inventories to site-specific problems. Some existing work had

previously been done in the development of a Landsat land cover inventory of the study area through the Southcentral Alaska Water Level B Study.[1]

Products were produced from this (Level B) data set that could be evaluated by the agency participants and used to demonstrate the feasibility of a regional land cover inventory. Following this evaluation, a new refined classification was undertaken as part of the INTRISCA Project to produce a land cover data set that was more recent, more specifically related to individual agency needs, and which could provide a comprehensive training experience for agency personnel.

In addition to the land cover inventory of the entire region involving all project participants, a number of subprojects were identified that concerned specific uses, and refinements of this data set were made for particular agencies and designated subareas. These subprojects also included subarea analyses that relied on multi-level remote sensing (e.g., high-altitude photography in addition to Landsat imagery) or on the development of multi-theme data sets incorporating other geographic data. Many of these analyses were relatively simple and occurred independently of, or in parallel with, the production of the overall Landsat-derived land cover data set; for example, manual photo-interpretations of multi-date Landsat imagery for measurement of inter-tidal zones and photo-interpretations of Landsat and RBV imagery to monitor urban development. Other subprojects, such as land suitability analyses and change detection, relied on completion and refinement of the Landsat data set and its incorporation with other data in a geographic information system. In all cases the subproject sought to apply an appropriate set of technologies and methods to the agency needs.

Some of the subprojects involved single agencies; others were cooperative between local and state agencies with related interests in a common geographic area. The following section identifies each subproject and its agency involvement.

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[1] Krebs, Paula V., J. Page Spencer, Kenneson G. Dean and Stuart E. Rawlinson, "Natural Resource Map of Southcentral Alaska: Landforms and Surficial Deposits, Geologic hazards, Land cover, Final Report: User's Guide", Geophysical Institute, University of Alaska, Fairbanks, Alaska, undated.

SUBPROJECTS

The INTRISCA demonstration project has been designed around a number of unique subprojects which respond to agency needs. An attempt has been made to preserve as much commonality as possible among the various subprojects; however, due to the number of agencies involved and their diverse land management problems, a complex set of requirements necessarily resulted (Table 2 lists the subprojects). Although it appeared that there was an unrealistically large number of proposed subprojects, there was a great deal of commonality among many of them (as shown in Table 3).

Table 3 shows the subprojects aggregated through common interest into thematic subprojects, with the various governmental agencies which required products from each. The general land cover subproject is a common need of all agencies and thus received the highest priority. Subprojects which involved lower levels of interagency participation were consequently assigned lower priorities within the overall demonstration project. Also shown is an indication of the analysis method most likely to be used in generating final products. As can be seen, two of the subprojects utilized only photointerpretive techniques while two required the use of a relatively sophisticated geographic information system. It should be noted that, while the Alaska Department of Fish and Game would have liked a wetlands inventory as part of this demonstration, that work has been deferred to a separate research project.

ALASKA REMOTE SENSING SUBCOMMITTEE

The Alaska Remote Sensing Task Force has recently been made a subcommittee of the committee on Natural Resource Information Management which, in turn, is a part of the Alaska Land Managers Cooperative Task Force. The Remote Sensing Subcommittee has served as the lead group for the program.

PROJECT PREPLANNING AND METHODOLOGY OVERVIEW

Training

As a means of accomplishing the project objectives, NASA provided a series of training sessions for participating agency team members. An intensive workshop format evolved; the principal goal of each workshop was to provide team personnel with hands-on training and field experience while meeting the other project objectives. Ground truth sites and training materials were selected to correspond with the planned work. NASA and its contractors, Airview Specialists and Technicolor Graphic Services, conducted a week-long air photo-interpretation workshop at Anchorage Community College to acquaint team members with the principles

TABLE 2

AGENCY SUBPROJECTS

Municipality of Anchorage

- General Land Cover
- Land Use Mapping
- Land Use Change Detection
- 208 Water Quality Management Analysis/Land Use Suitability

Matanuska-Susitna Borough

- General Land Cover
- Land Use Mapping
- Land Use Suitability
- Land Use Change Detection
- Road Network Mapping

State of Alaska

Department of Natural Resources
Land and Resource Planning

- General Land Cover of Lower Susitna Basin
- Land Capability Analysis in Susitna Basin

Department of Natural Resources
Division of Forest, Land and Water Management

- General Land Cover of Lower Susitna Basin

Department of Fish and Game

- Cook Inlet Intertidal Zone Measurement and Change Detection
- Habitat Classification in Lower Susitna Basin
- Wetlands Inventory in Lower Susitna Basin
- General Land Cover

TABLE 3

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THEMATIC SUBPROJECTS

Subprojects \ Agency	Municipality of Anchorage	Matanuska-Susitna Borough	Dept. of Nat. Res. Land/Res. Planning	Dept. of Nat. Res. Forestry	Department of Fish and Game	Weighted Total	Priority	Analysis Method
General Land Cover	x	x	x	x	x	10	1	DIG
Land Use Mapping	x	x				4	3	PI/DIG
Change Detection	>	>				2	5	PI/DIG
Land Use Capability Analysis	x	x	x			6	2	GIS
Forest Inventory			>	x		3	4	PI/DIG
Wetlands Inventory	>	>			x	4	3	PI/DIG
Habitat Analysis					x	2	5	PI/DIG
Intertidal Zone Measurement					x	2	5	PI
Road Network Mapping		x				2	5	PI/DIG
Water Quality Mgmt.	x					2	5	DIG/GIS

Note: x = 2 pt. Primary
> = 1 pt. Secondary

Analysis Method
DIG: Digital Analysis
GIS: Geographic Information System
PI: Photo Interpretation

of aerial photographic interpretation using Landsat imagery, U-2 high altitude color infrared photography, and low altitude natural color aerial photography. Instruction was given in the use and care of mirror stereoscopes and zoom transfer scopes. As part of the training effort, it proved beneficial to make reconnaissance visits to the field. Eagle River, a community ten miles north of Anchorage, was selected for this purpose because it provided a diversity of training sites, vegetation types, and land uses. This procedure proved to be advantageous not only for interpretation, but also for field checking. Due to the low accessibility of much of the study area, an aerial flight was made over much of the region at low altitude and 35 mm pictures were taken. Each photographed site was predetermined from examination of the U-2 photographs and was plotted on a USGS base map.

By conducting these preliminary reconnaissance missions and by photographing areas from the air and ground, anticipated problems were alleviated during the interpretation process. The agency field teams were provided with interpretation keys which could prove helpful in identifying problem cases.

Another advantage of the reconnaissance phase of training was that it allowed agency personnel to become more familiar with the study area. It allowed the agency personnel to learn what types of phenomena were likely to appear on the imagery as well as how they would appear. The result of this activity was a considerable savings in interpretation time.

In addition to NASA providing air photo-interpretation training, a digital analysis workshop was held at NASA/Ames Research Center to acquaint users with digital image enhancement, classification, and statistical methods. This aspect of the training provided users with the ability to begin looking at land use/land cover in terms of spectral reflectance differences, and to understand the limitations of utilizing Landsat imagery. Training was provided on the IDIMS system, which was used for training site selection and classification evaluation.

In addition, the State of Alaska, through the University of Alaska Geophysical Institute in Fairbanks, conducted a one week seminar on introductory remote sensing. In all training situations, team members were given materials and manuals for use during the project as well as for use in future projects.

Personnel

The personnel of the project team fluctuated to some extent. Because of other priorities at the time, Kodiak Island Borough was able to send a staff person to only one training

session. The Kenai Peninsula Borough was also unable to send staff to training sessions and withdrew from the project. Staff assigned from the Department of Fish and Game also changed as the project got underway. Overall, however, the project team has remained constant. Toward the end of the project two NASA personnel resigned and a new project manager was assigned. However, this caused no significant delays or changes to the overall project. Project team members are listed in Table 4.

STUDY AREA SELECTION

The study area originally envisioned during preplanning meetings was to include both the upper and lower Cook Inlet of Southcentral Alaska. Geographically, this area included Kodiak Island Borough, the Kenai Peninsula Borough, the Municipality of Anchorage, and the Matanuska-Susitna Borough. As previously mentioned, Kodiak Island Borough staff utilized only the color infrared aerial photography to meet their objectives and did not participate in the classification of land cover using Landsat data. Kenai Peninsula Borough did not have the staff available to participate. Thus, the final study area boundaries were limited to the Municipality of Anchorage and a portion of the Matanuska-Susitna Borough. Fig. 1 shows the final boundaries of the study area, covering some 22,000 sq. miles.

DESCRIPTION OF DEMONSTRATION AREA

The southcentral study region includes areas draining into the upper Cook Inlet. The area, approximately 22,000 square miles, is characterized by rugged, mountainous terrain with important exceptions in the lowlands bordering upper Cook Inlet, the Susitna Basin and Anchorage lowland. The towering Alaska Range forms the western and northern boundaries of the region, and the Talkeetna and Chugach Mountains bound the region on the northeastern, eastern and southern borders.

The Susitna Basin is dominated by the Susitna River and its tributaries, which originate in the Alaska Range and Talkeetna Mountains. The Susitna lowlands feature notable concentrations of lakes, a majority of which were formed by glacial processes.

The Anchorage peninsula occupies a roughly triangular piece of land. The western portion of the Municipality is a lowland area which is part of the Cook Inlet-Susitna lowlands physiographic province. The Anchorange lowland is an area of generally low relief that slopes gently westward from the Chugach Mountains in the east.

The Cook Inlet-Susitna lowland, with an elevational range from sea level to 500 ft., is a broad basin with local

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(continued on next page)

Table 4, continued

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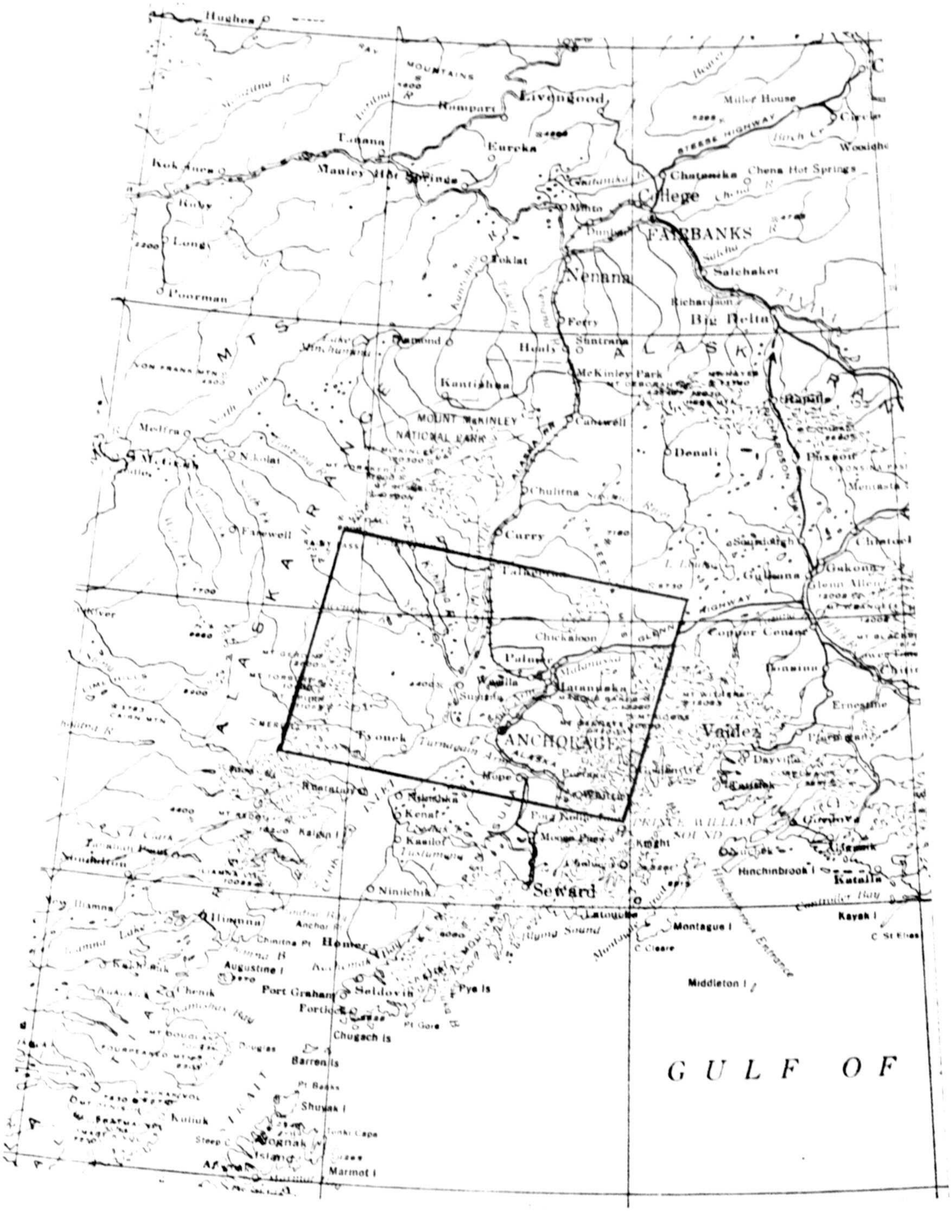

FIGURE 1. STUDY AREA

relief of 50 to 250 ft. The retreat of past glaciers left a topography dominated by such glacial features as ground morains, drumlin fields, eskers, outwash plains and kettles. Large portions of the basin are not well drained, and lakes and wetlands are abundant. In addition to glacial deposits, stream and terrace gravels are prevalent along many of the drainages.

The lowland has two main arms, the largest of which is the Matanuska Valley south of the Talkeetna Mountains. The second is the Susitna River Valley which extends from Cook Inlet north to the Alaska Range.

SELECTION OF A CLASSIFICATION SYSTEM

Because the primary objective of the INRISCA project was to provide various user groups with uniform data sets (standard land cover classifications) derived from Landsat imagery and high altitude aircraft photography, it was mandatory that a land cover classification system be used to meet all agencies' needs and objectives.

The collection of land use/land cover data has been the concern of many agencies throughout Southcentral Alaska. Too often, data have been collected independently and without coordination, resulting in duplication of effort, incompatible land use/land cover classifications, and short term validity. Alaska has some unique vegetative types that do not accurately fit into standardized classification systems of the lower 48 states.

The land use classification system developed for the Inter-Agency Steering Committee on Land Use Information and Classification by James R. Anderson, and published by the Geological Survey under the title, A Land Use Classification System for Use with Remote-Sensor Data, Geological Survey Circular 671, (1972), has been found by numerous user agencies in Alaska to be inappropriate and not applicable for use in Alaska. As a result of this finding an interagency task group set out in 1975 to develop a vegetative classification system for use in Alaska. In December, 1975 a first draft had been prepared for broad distribution statewide. The system selected for consideration was that of Les Viereck of the Institute of Northern Forestry. After considerable review a second version was drafted in January of 1976 entitled, A Provisional Classification Framework for Alaskan Vegetation. This version was again distributed for comment and review, and changes were made. This resulted in a third and fourth revision which were completed on June 1, 1979. On November 20, 1979 a meeting of federal and state agencies statewide was held to finalize the classification and test its applicability to agency needs. The fourth version was selected for adoption, down to the third level. A meeting scheduled in January of 1980 was held for the purpose of selecting and adopting this classification system.

This has provided, for the first time, a standardized and uniform vegetation classification for interagency use statewide and has begun to resolve problems previously mentioned.

The INTRISCA project has adopted a modified version of the Viereck Vegetation Classification System as the one to be used by participating agencies in an attempt to establish a standardized Remote Sensing Land Cover classification usable at all levels of government, and in an attempt to be compatible with the statewide system adopted in January of 1980. Figure 2 illustrates the system used.

CLASSIFICATION SCHEME

The classification scheme used in the digital analysis of the Susitna basin was initially based on levels II and III of the Viereck and Dyrness system. The classification scheme evolved to reflect the spectral data, and available ground data information. The information classes attained in the classification correspond to the quantity and quality of training sites, spectral characteristics of the digital data, and the verification of spectral class assignments during the evaluation workshops.

The classification scheme is based on physiognomy, that is, plant communities which are similar in lifeform. The land cover categories are described according to dominant lifeform, site moisture, and associated landscape elements. Within the same land cover category local variations in species composition may be present; however, the overall appearance will be similar. The classification scheme developed for the Susitna basin, based on analysis of Landsat satellite data, resulted in the following seventeen land cover/land use categories:

Shallow and Sedimented Water

Shallow lake shelves, turbid lakes, deltaic plumes, and rivers and lakes with high sediment loads comprise this class. Emergent and aquatic vegetation may also be present.

Deep and Clear Water

Includes many of the hundreds of inland lakes in the Susitna basin.

Black Spruce Bog

That community comprised of a Black Spruce overstory with an understory of mosses, berries and small shrubs. Also includes bogs with a major shrub component. This cover type is characterized by impeded drainage, saturated soils and in many cases, underlain with permafrost.

FIGURE 2

INTRISCA

GROUND TRUTH SCHEME

- 100 BARREN LAND
  - 110 Mudflats
  - 120 Bare soil
  - 130 Bare exposed rock
- 200 WATER RESOURCES
  - 210 Deep water
  - 220 Shallow/sedimented water
  - 230 Freshwater lakes and streams
- 300 AGRICULTURAL LAND
  - 310 Cropland & pasture
  - 320 Other agricultural land
- 400 URBAN
  - 410 Residential
    - 410.1 high density
    - 410.2 low density
  - 420 Wooded residential
  - 430 Commercial/industrial/institutional
  - 440 Pavement/transportation
  - 450 Mobile homes
  - 460 Mixed (undifferentiated) urban
- 500 EXTRACTIVE INDUSTRY & NATURAL DISASTERS
  - 510 Strip mines, quarries & gravel pits
  - 520 Clear cuts
  - 530 Forest fire areas
- 600 NATURAL VEGETATION
  - 610 Rangeland
    - 611 Herbaceous meadow (grassland)
    - 612 Shrub
      - 612.1 Tall shrub (Alder)
      - 612.2 Low shrub
    - 613 Mixed rangeland
  - 620 Forest
    - 621 Broadleaf
    - 622 Conifer
    - 623 Conifer broadleaf
    - 624 Broadleaf-conifer
  - 630 Woodland
    - 631 Broadleaf
    - 632 Conifer
    - 633 Conifer broadleaf
    - 634 Broadleaf-conifer
  - 640 TUNDRA
  - 641 Herbaceous Tundra
  - 642 Shrub Tundra
  - 643 Alpine (Mat & cushion tundra)
- 700 PERENNIAL SNOW AND ICE
  - 710 Snow and Ice
  - 720 Glacier

Grass and Shrub

Encompasses those communities with a major vegetative component of shrubs, grasses and sedges. This class occurs as tundra above the treeline, as the primary successional community on timber cuts, and within tidal marsh areas.

Coniferous Forest

This class includes any areas which have a dominant crown cover of coniferous trees (white and black spruce). Includes open and closed coniferous forests and may have up to approximately one-third deciduous crown cover.

Mixed Coniferous/Deciduous Forest

This class occurs whenever the Deciduous or Coniferous vegetative components cover at least one-third of the overall vegetative cover.

Deciduous Forest

Encompasses open and closed forests with deciduous trees as the major vegetative component. This class can include up to one-third coverage of conifers; usually the conifers present are shorter than the deciduous crown canopy. Main species found include birch and aspen with an understory of various forbs, grasses and shrubs.

Barrens

All bare rock or soil surfaces with less than one-third vegetative cover. Includes bare rock outcrops on the major mountain ranges, tidal mudflats, floodplains, sandbars, and gravel pits.

Alpine Tundra

Basically, mat and cushion, low-lying vegetation commonly found above the treeline (berries, prostrate shrubs, lichens, etc).

Snow and Ice

This class includes all perennial snow and ice fields in the major mountain ranges surrounding the Susitna basin.

Agricultural Fields

Growing crops, pastures and fallow fields are included in this class. A large proportion of agricultural fields can be found in the Mat-Su Valley between Wasilla and Palmer.

Commercial and Industrial

Encompasses all commercial centers, industrial complexes, shopping centers, airport complex and port facilities found in Anchorage, Eagle River and Palmer.

Transportation Facilities
Major highways, roadways, and airport runways comprise this class.

High Density Residential
This class includes condominiums, apartment complexes, mobile home parks, and other multiple family dwellings.

Low Density Residential
Basically, this class encompasses single family dwelling neighborhoods.

Cloud and Cloud Shadow

The information classes were generalized, when necessary, to maintain a high level of accuracy. Spectral classes which were not consistently identified during the evaluation workshops by agency participants were grouped into a more generalized information class. For instance, spectral confusion between Black and White Spruce necessitated grouping these two species into one (more accurate) class: conifer. However, these two species could be manually differentiated with a map overlaid on the color-coded classification if the interrelationship of vegetation and terrain is known. In this case, Black Spruce occupy depressional basins with impeded drainage, while White Spruce are found on slopes with integrated drainage. The Landsat classification will provide the most reliable and useful information when used in conjunction with ancillary data. During the final phase of analysis, the information classes for the two data sets were examined in overlapping sections of the data to identify classification discontinuities. Minor discontinuities between scenes were expected, considering the changing phenology of vegetation between the beginning and end of August, the dates of the Landsat scenes. Differences between the two data sets were minimized by renaming of spectral clases in one data set to coincide with identification in the other data set.

The classification scheme which was used to characterize the Susitna basin was devised to satisfy the needs of a number of state agencies in an effort to demonstrate the use of Landsat satellite data, while providing a reliable land cover inventory for the region. The classification scheme was generalized to maintain a high degree of accuracy and consistency in both Landsat scenes, although greater detail exists in each individual scene.

FIELD DATA COLLECTION CONSIDERATIONS

After training courses and preliminary field reconnaissance

missions were completed, training sites were selected and plotted on acetate overlays on the U-2 color infrared photography and on USGS topographic maps. A training site is a geographic location on the ground. The use or land cover at that site is recorded and used to assist in classifying the Landsat digital data. Because of the large area covered within the demonstration project, the tasks of selecting training sites, doing air photo-interpretation, and conducting field work were distributed among the various agencies. For example, the Municipality of Anchorage did all the air photo interpretation and field checking within its jurisdictional boundaries. Particular emphasis was placed on urban and rural land uses, although several training sites did include vegetative land cover. The Matanuska-Susitna Borough Planning Department concentrated on selecting training sites within the corporate limits of Palmer and Wasilla which included primarily rural land uses and agricultural areas. The State of Alaska, Department of Natural Resources, Division of Forestry selected training sites in areas which had commercial forest potential in the Susitna Basin. The Land and Resource Planning Section, also within the Department of Natural Resources, concentrated on selecting training sites in the Susitna Basin that did not have commercial forest potential, and limited their efforts to the Parks Highway corridor between Talkeetna and Wasilla. The State of Alaska, Department of Fish and Game, participated in several subprojects, most of which required only photo-interpretation of high altitude aerial photography and which did not require digital classification of Landsat imagery.

Because of the diversity in land cover types found within the project area, it was decided early on that user selection of the sampling area would be most efficient and accurate in producing the desired classification.

TRAINING SITE DATA FORMS

A standardized training site data sheet was prepared for use by each agency (Figure 3). The form was designed so that it served as an index for both low and high altitude aerial photography and topographic maps. Space was provided for a notation of each frame giving mission number, roll number, date, project area, scale and film type. The forms were designed to be used in conjunction with the land use/land cover classification system and they permitted a summarization of each training site in terms of land cover type, percentage of cover, community type and physiography. Each agency assigned a code number to each training site for future use and reference. (Figures 4 and 5 illustrate some of the land cover studied in the training sites).

FIGURE 3

TRAINING SITE DATA SHEET

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GENERAL

Observer ____________ Date ____________

Quadrangle ________ Scale ________ Time ________

Locality Description

Township______ Range ________

Section ______ ______ ______

Latitude/Longitude__________

Roll ________

Photography Flight Line & Frame No. ________ BLM Code ______

Photo Date ________ Film Type ________ Test Site No. ________

Road Access to Site__________Aircraft Access to Site______

Other ____________

PHYSIOGRAPHY (See attached legend)

Elevation__________Slope__________Aspect N S E W

Position on Slope (Toe, Mid, Upper, Ridge)____________

Macrorelief____________ Landform ____________

VEGETATION (See attached legend)

Level I Forest__ Woodland___ Tundra__ Grassland__ Shrubland__Aquatic__ Wetland__

Level II ____________ Level III ____________

Community Type (Dominant species in order of prominance, phenology)

Overstory ____________ 1. ______ 2. ______ 3. ______

Intermediate ____________ 1. ______ 2. ______ 3. ______

Ground Layer ____________ 1. ______ 2. ______ 3. ______

Cumulative Vegetative Ground Cover (enter number of crown cover classes after each species listed above)

1.	95 - 100%	4.	25 - 49%
2.	75 - 94%	5.	10 - 25%
3.	50 - 74%	6.	- 10%

Percentage Cover

____Coniferous Trees
____Deciduous Trees
____Tall Shrubs (2 m)
____Medium ht Shrubs (.5-2 m)
____Dwarf Shrubs (10-50 cm)
____Prostrate Shrubs (10 cm)
____Grass & Sedges
____Forbs
____Mosses & Lichens
____Bare soil
____Rock
____Water

LAND USE ____________ (See attached legend)

Soils: (optional) Sand ____Silt___Clay___Gravel___Loam___Stones_____

Bedrock ____

Moisture: Dry ________ Moist ________ Saturated ________

COMMENTS

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B. Agricultural Field

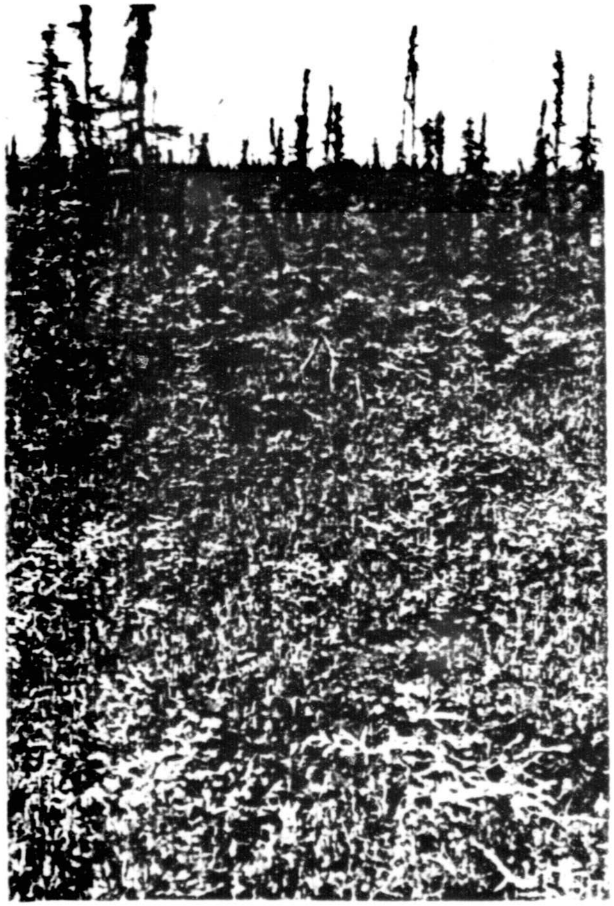
A. Deciduous Forest

C. Aerial Photograph of Anchorage International Airport

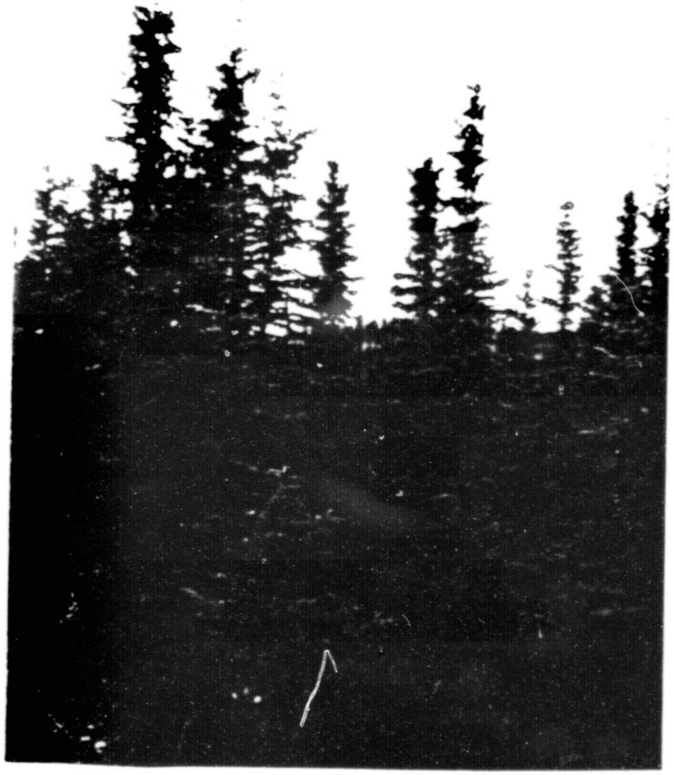
FIGURE 4 LAND COVER AT SELECTED TRAINING SITES

FIGURE 5 LAND COVER AT SELECTED TRAINING SITES

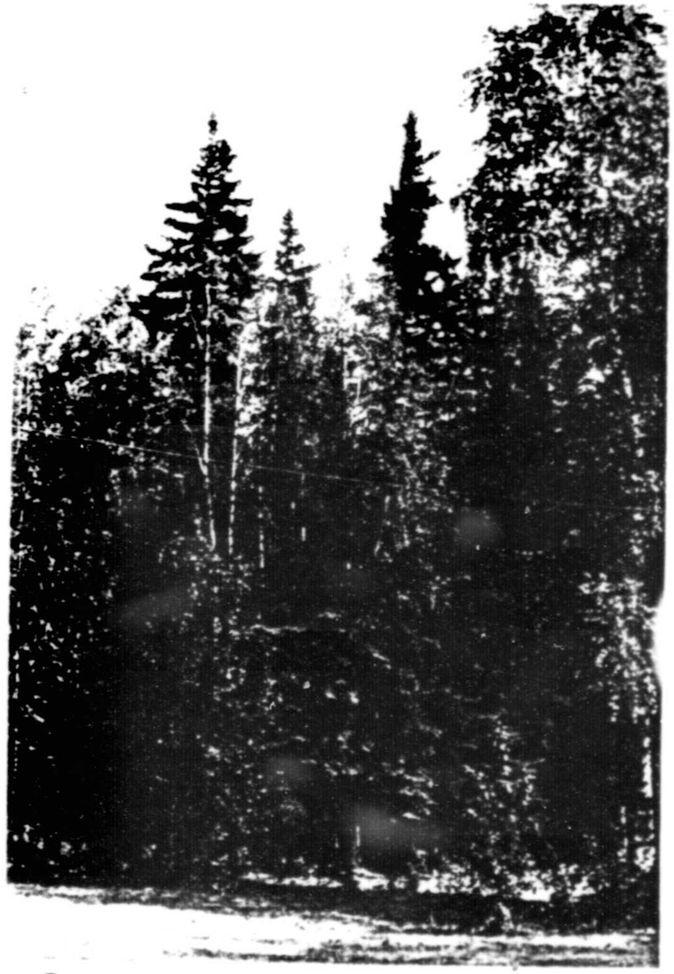
Typical Vegetative Communities



A. Black Spruce Bog



B. Black Spruce Forest



C. Mixed Deciduous/Coniferous Forest

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MINIMUM-AREA MAPPING UNITS

For photo interpretation and training site sampling the concept of the minimum-area mapping unit was used to alleviate potential problems due to significant resolution loss. Pixel size is restricted to approximately 1.1 acres on Landsat, and because of the extraordinary amount of time and expense involved with classifying training sites on IDIMS, it was felt necessary to develop an acceptable minimum area mapping unit. This is simply a minimum area measure defined in terms of the dimension of any land use/land cover at mapping scale. A land use/land cover occupying a smaller total area on the map would not be mapped as a distinct land use or land cover, but would be merged with a land cover in the most logical manner possible. In this case, land covers with similar spectral reflectances or values would be merged during the statistical clustering process.

For purpose of photo-interpretation of land cover, particularly vegetation, 40 acres was selected as the optimum size for training sites. For urban land uses, training sites were kept to a 5 acre minimum area mapping unit, and larger if possible. Urban land uses were more difficult to map because of their small size and diversity. For example, in the Palmer/Wasilla area of the Matanuska-Susitna Borough, many training sites were less than 5 acres in size and in some cases could not be located on the IDIMS display.

CHAPTER III

CHARACTERISTICS OF LANDSAT AND CIR PHOTOGRAPHY AND IMAGE PROCESSING SYSTEMS

To provide the non-technical users of this document with an understanding of remote sensing, a brief description of the Landsat system and other remotely sensed data is presented in this section. The systems used in this demonstration project to process, manipulate, analyze, classify and output the data are also described.

LANDSAT

Remote sensing is not a new concept in land use and resource management. Aerial photography has been used for many years as a basic tool in surveying land areas. The complete Landsat system consists of an observatory or observatories in near-polar Earth orbit and ground installations to receive, process and disribute the data provided by the sensors carried on the satellites.

The acquisition of remote-sensor imagery depends upon the detection and recording of electromagnetic energy reflected or emitted from surfaces of natural or man-made features that are within the field of view of the sensor. When energy (sunlight) strikes a feature it is either reflected, absorbed, or transmitted. The degree of reflection, absorption or transmission is a function of the properties of the material and the wavelength of the energy. Various earth resources and features respond differently to energy of various wavelengths depending upon their chemical and physical properties, surface configuration and roughness, intensity of illumination and angle of incidence. When earth resources and features are recorded on remote sensor imagery, the various responses of earth features form patterns which provide means for discrimination. Through analysis of these patterns and their relationship to each other, an individual can deduce the identification of these patterns. Various types of remote sensors record in different energy bands. The multispectral scanner onboard Landsat records data in four different bands of the electromagnetic spectrum.

Landsat produces images of Earth--not with a camera but with a multispectral scanner (MSS). The multispectral scanner is a line-scanning device that uses an oscillating mirror to continuously scan perpendicular to the spacecraft's orbital path.

The MSS records information in both visible wave lengths and in parts of the electromagnetic spectrum which are invisible to the eye (near-infrared). The MSS records differences in

sun reflectance from earth-surface features.

Water, vegetation, minerals, and other natural and man-made features reflect light or emit radiation in different intensities for different bands of the electromagnetic spectrum. Each feature has its own unique reflection pattern, an identifying signature that makes it possible for remote sensers to differentiate surface features. The MSS takes four readings for each 1.1 acre area on the ground: one for the intensity of green light reflected, one for the intensity of red light reflected, and two for the intensity of infrared. These intensity levels are converted into electronic signals (digital form) that are sent to ground stations. This digital data is stored on computer tapes that can be used to analyze the 115-mile-square Earth scene (although the MSS scans a continuous path, the data is cut into a standard film format, thus providing a film product coverage for 115 miles on each side).

Landsat's singular advantage over conventional photographic systems is that it gathers data in a computer-compatible format that facilitates processing and use of the data. Landsat data can be used in either its photographic form or in its computer-tape (digital) form. If the photographic products are chosen for analysis the procedures are almost identical to those used for interpreting conventional aerial photographs. Approximately 5,000 frames of CIR photography (stereo coverage at 1:60,000 scale) are required to cover one scene of Landsat data.

Computer processing (computer-aided analysis techniques) is more complicated than photo-interpretation but can be faster and can yield more detailed results. The computer can normally identify objects of as little as 1.1 acre (pixel) while photo-interpretation techniques are generally limited to objects of 5 to 10 acres or larger. Using the computer, data can be analyzed statistically and used to provide "classified" imagery highlighting specific types of land cover with arbitrarily chosen colors as on maps.

At an altitude of approximately 570 miles, Landsat circles the earth 14 times daily, scanning a particular geographic locale every 18 days. This high volume of information, broad-area coverage, and repetitive sweeping provides a variety of opportunities for practical application of the data to resource and land use planning related tasks and problems.

COLOR INFRARED PHOTOGRAPHY

The State of Alaska in conjunction with various federal agencies has undertaken a high altitude aerial survey of the entire State of Alaska. For the past three years, the U-2 and WB57 aircraft have been flying the state taking color

infrared aerial photographs. The University of Alaska, Geophysical Institute, Fairbanks and the Bureau of Land Management, Anchorage are the repositories for all film products. The color infrared photography was extensively used throughout the INTRISCA project.

The Lockheed U-2 is a single place aircraft designed for sustained operation at high altitude. At its normal cruise altitude of 65,000 feet the U-2 is above most atmospheric turbulence and wind factors, providing an exceptionally stable platform for remote sensor operation.

Color infrared film is sensitive to the green, red and near-infrared (500-900 nanometer) portions of the spectrum and is widely used in aerial and space photographic surveys for land use and vegetation analysis. Living vegetation reflects light in the green portion of the visible spectrum to which the human eye is sensitive. Additionally, it reflects up to ten times as much in the near-infrared (700-1100 nanometer) portion of the spectrum, which is just beyond the range of human vision. When there is a decrease in photosynthesis, whether caused by normal maturation or stress, there is a corresponding decrease in near-infrared reflectance. Living or healthy vegetation appears as various hues of red in color infrared film. If diseased or stressed, the color response will shift to browns or yellows due to the decrease in near infrared reflectance. This film is also effective at haze penetration since blue light is eliminated by filtration.

IMAGE ANALYSIS SYSTEMS

DESCRIPTION OF SYSTEMS USED FOR CLASSIFYING

INTRISCA project team members were given hands-on training on the Interactive Digital Image Manipulation System (IDIMS). IDIMS is comprised of several interactive terminals and a COMTAL CRT display unit which is capable of displaying color composite images, graylevels, and pseudocolored graylevel images. A 512 x 512 display area allows a portion of a Landsat scene to be viewed and displayed either as raw digital data or as false color images, or as pseudocolored classified scenes. A track-ball cursor allows user selection of subareas of each scene, which can be enlarged. The HP3000 computer and two tape drives facilitate magnetic tape input; disc drives serve as additional memory and as working storage. Output devices include the CRT, terminals, tape drives, a Dunn camera system, a Dicomed film recorder, and a line printer.

The clustering algorithm operates on data that may be generated through either a random sample or an operator selected sampling area, or a combination of both. The

system utilizes a maximum likelihood classifier and offers a wide range of data manipulation software.

Once classified, data can be aggregated by IDIMS into political units, such as traffic analysis zones, census tracts or game management units. This is accomplished on IDIMS through the Geographic Entry System (GES).

EDITOR (ERTS Data Interpreter and TENEX Operations Recorder) is a system of software that has developed and evolved into a complete image processing software system, useful for analyzing Landsat digital data. The system, installed on the I4-TENEX system at NASA/Ames Research Center, provides an analyst with the tools necessary to perform all phases of Landsat digital analysis.

The EDITOR System was developed at the Center for Advanced Computation, University of Illinois at Urbana-Champaign, and is designed to provide a three-fold system for interactive image processing, file management, and ILLIAC IV interfacing. First, the interactive image processing system allows for the manipulation and display of LANDSAT digital data by the analyst at a local level. Second, the file management system controls both input/output of data and editing of file structures. Third, files are structured through the two preceding parts of the system for submitting data to the ILLIAC IV for batch processing. All three are accessed and controlled through the EDITOR software structure.

PERIPHERAL OUTPUT DEVICES

DICOMED D-47 FILM RECORDER

The D-47 is a film recorder manufactured by the Dicomed Corporation. It is an output device capable of generating a single black-and-white or color negative, a single color positive transparency, or individual black-and-white or color Polaroid prints on standard 4x5 Polaroid film. Input is via a magnetic tape with three separate files, one for each color filter: blue, green, and red.

Programs run on the HP3000 computer allow users to select colors for the land cover classes in the classified image prior to the generation of the DICOMED products. The D-47 was used to generate many of the output products for the INTRISCA project.

DUNN 631 COLOR CAMERA

The Dunn 631 Color Graphic Camera System is an output device designed for recording photographic hard copy from the

signal generated in a CRT, through display on a black-and-white monitor. Full color, black-and-white, and color separation images can be recorded on 8 x 10 print film and 35 mm slide film. The camera system is an efficient and rapid means of transferring computer images from a CRT display to film.

VERSATEC ELECTROSTATIC PLOTTER

An electrostatic plotter is an output device which offers high output speed, reliability, and low plotting costs. The plotter prints in widths ranging from 22 to 72 inches. A Versatec plotter was used for this project and includes the following capabilities:

1) A character generator (standard) allows the unit to operate as a line printer as well as a plotter. A simultaneous print-plot option (SPP) allows hardware-generated characters to be overlayed onto the plot patterns.

All Versatec wide plotters utilize a dual array writing head which writes an overlapping dot structure. This produces solid, continuous plotted lines and patterns. The high resolution writing head also permits generation of various degrees of shading, from light gray to solid black.

The wide plotters employ a shaft encoder to ensure a vertical accuracy of 0.2% or 15 mils, operating at maximum speed. An equivalent horizontal accuracy is assured by the precision-engineered stationary writing head. The shaft encoder and servo system decelerate the paper gradually to avoid overshoot.

Output scales can be varied so that plotter maps overlay various scale base maps. Figure 6 illustrates a sample of the output capability.

Other peripherals and systems utilized include an ALTER digitizer and COMPLOT plotter (tied in to the EDITOR System), IBM 360/67 computer, CDC 7600 computer and SEL computer.

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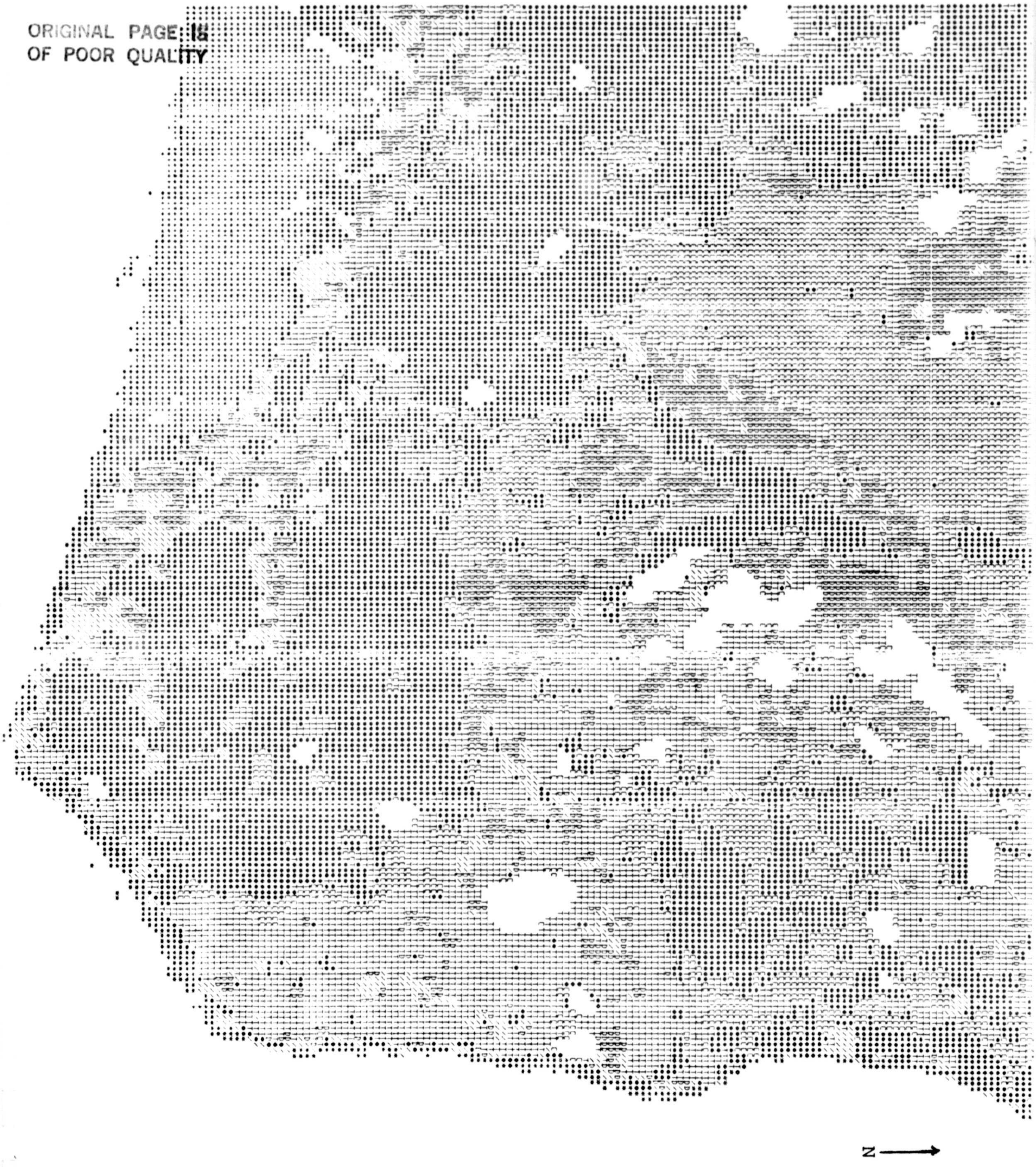


FIGURE 6. VERSTEC ELECTROSTATIC PLOTTER MAP

CLASSIFICATION OF 1978 DATA,
INTRISCA, SUSITNA SCENE GROUPED DATA.

CHAPTER IV
TECHNICAL APPROACH

INTRODUCTION

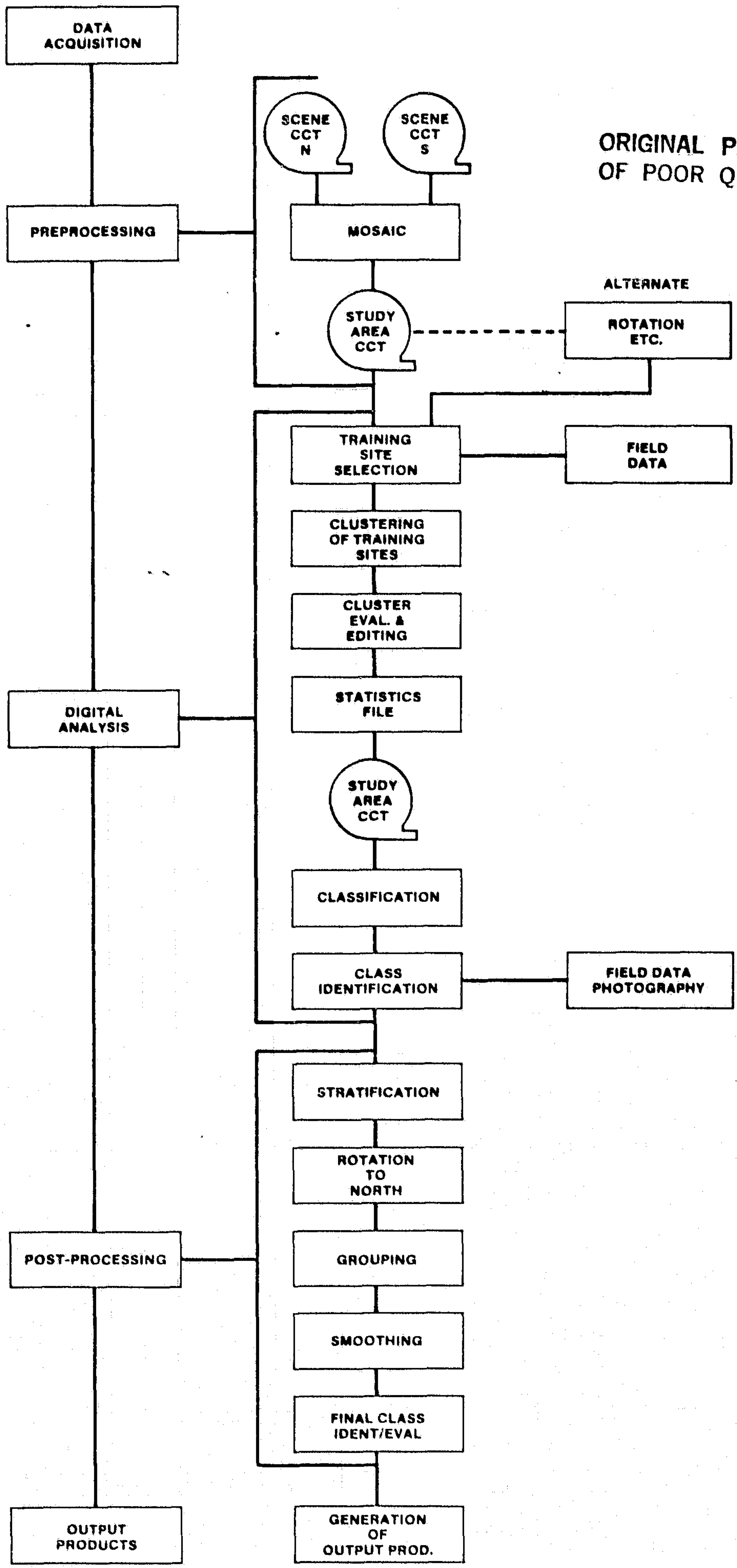
The following is a generalized representation of the work flow in the digital analysis of Landsat data. Technical papers describing various phases in the analysis of the INTRISCA Landsat data appear in the appendices. (Figure 7 illustrates the technical work flow for the INTRISCA project). The INTRISCA project is due in part to the Southcentral Alaska Water Level B study which utilized Landsat digital data to provide land use/land cover information for future management of land and water resources. The land cover classification for the Water Resource Study was completed by Dr. P. Krebs and P. Spencer of the University of Alaska. Products from the classification were evaluated by NASA and participating agencies to determine their usefulness in meeting state agency needs. As part of the INTRISCA project, NASA corrected major classification errors through the use of stratification techniques. Following the evaluation, NASA began a new classification to produce a more recent data set which was more specifically related to individual agency needs.

One source of classification error in Landsat analysis work is the result of spectral confusion between two distinct land cover categories. Each spectral class is supposed to represent a specific land cover category. However, problems arise when two distinct land cover categories have similar spectral reflectance values. Stratification techniques have been developed to resolve this type of classification error. Where problem areas exist, boundaries are delineated to encompass the misclassified spectral classes. Conflicting spectral classes within specified polygons are reassigned to the correct land cover category.

Preliminary stratification strategies involved reassignment and reidentification of spectral classes within physiographic provinces, Anchorage and Eagle River urbanized areas, and the Palmer agricultural region. Refinements to the Level B classification (originally with 43 spectral classes) separated an additional six land cover categories: grasslands, alpine tundra, commercial/industrial, low- and high-density residential, and agricultural fields. Color-coded Dicomeds of the Level B classification before and after stratification have been generated for the Anchorage urban area (Figure 8).

The following chapter briefly describes the technical processes utilized to generate the new classifications, data sets, and other products of the demonstration project.

FIGURE 7 TECHNICAL WORK FLOW CHART



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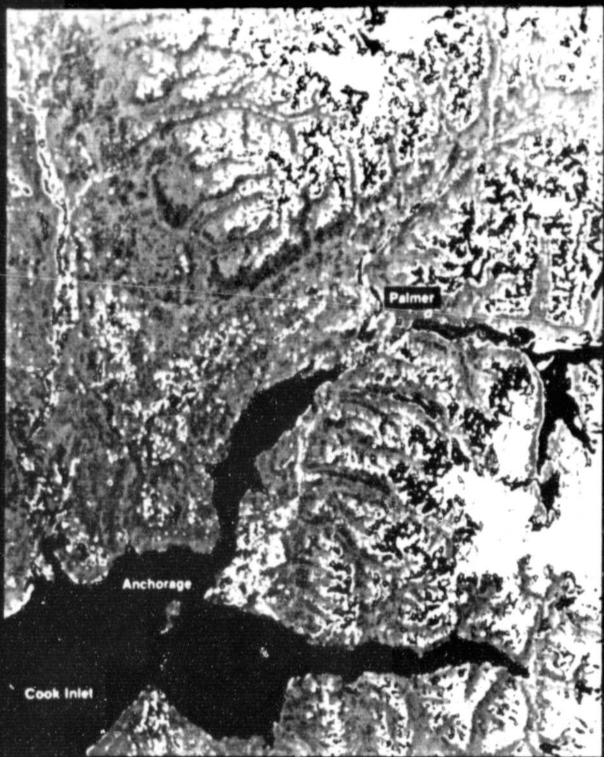
STRATIFICATION RESULTS

INTEGRATED RESOURCE INVENTORY FOR SOUTHCENTRAL ALASKA



Water Resource Study (Level B)

The primary goal of the Southcentral Water Resources Study (Level B) is to formulate a comprehensive strategy for future management of the region's water and related land resources. The Bureau of Land Management is responsible for management of lands within south-central Alaska, and has contracted with the University of Alaska Geophysical Institute to provide land use/land cover information utilizing computer-aided analysis of Landsat digital data. The land cover classification for the Water Resources Study (shown at left) was completed by Dr. Krebs and P. Spencer.

To meet resource management objectives and information needs, state, federal, and local agencies of the Cook Inlet region are working in cooperation with NASA to implement remote sensing techniques in the development of a resource data base. The Integrated Resource Inventory for Southcentral Alaska (INTRISCA) is part of an Applications Systems Verification and Transfer (ASVT) project. INTRISCA is a multifaceted demonstration project undertaken to formulate and evaluate plans and alternatives for the application of remotely-sensed data in the planning and decision-making process. As part of the ASVT, NASA is responsible for evaluating the Level B Water Resources classification.

Land Cover Legend

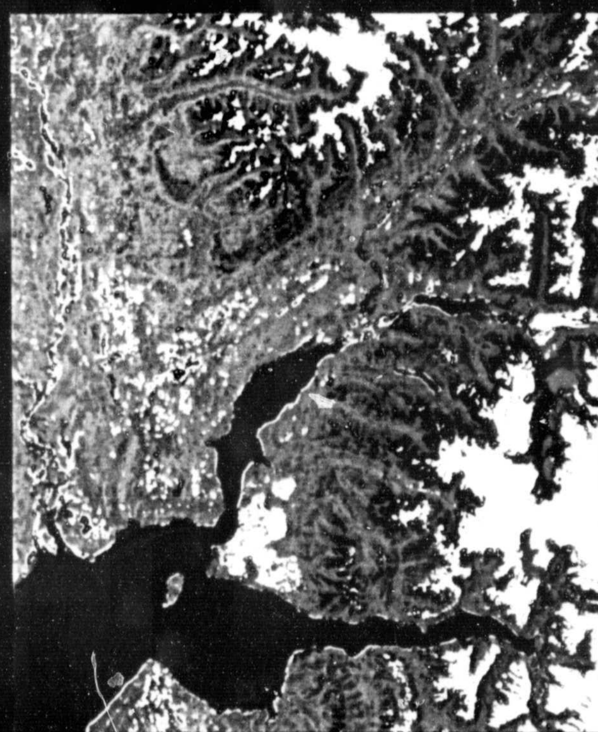
Coniferous Forest	Barrens
Deciduous Forest	Marsh
Deciduous Forest/Wetlands	Deep Water
Mixed Forest/Wetlands	Shallow/Turbid Water
Mixed Rangeland	Commercial/Industrial
Grasslands	Residential-high density
Alpine Tundra	Residential-low density
Mudflats	Snow/Ice/Cloud

Stratification of Level B

Classification errors in Landsat analysis work are the result of spectral confusion between two distinct land cover categories. Each spectral class is supposed to represent a specific land cover category. Problems arise when two distinct land cover categories have similar spectral reflectance values, i.e., one spectral class encompasses two distinct land cover categories. Stratification techniques have been developed to resolve this type of misclassification. Where problem areas exist, boundaries are delineated and digitized from maps. Conflicting spectral classes within specified polygons are reassigned to the correct land cover category.

Evaluation of the Level B classification indicated a number of problems which could be resolved with stratification. Most notably, in the uplands, north-facing slopes were classified as water; bedrock exposures and alpine tundra were misclassified as urban. In addition, many land cover categories were identified as one category in the lowlands and some other category in the uplands. With stratification, spectral confusion was eliminated by isolating uplands (above 1000 feet) and the Anchorage urbanized area. Spectral classes were renamed within these two polygons, further refining the classification (shown at right).

In the fall of 1979, digital analysis work will be undertaken by NASA, in collaboration with agency personnel, to produce a land cover data base that is specifically related to individual agency needs and which can provide a comprehensive training experience for agency personnel. In addition to the land cover inventory of the entire region, a number of other subprojects have been identified by the agencies which involve digital analysis and manual photointerpretation of Landsat data and high-altitude CIR photography.



NASA
National Aeronautics and Space Administration

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FIGURE 8. Level B Stratification Results

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DATA ACQUISITION

A minimum of four kinds of data are usually acquired in preparation for the generation of a Landsat land cover classification: 1) Landsat digital data, in the form of computer-compatible tapes (CCTs), 2) false-color photographic representations of the digital data, 3) field data, and 4) color infrared U-2 photography. Lower-altitude photography may also be gathered, if available, depending upon the types of land cover classes to be identified. Appendix A, Imagery Acquisition, pertains to the acquisition of data for the INTRISCA classification. Team members conducted low altitude overflights of portions of the study area. 35 mm oblique photographs were taken of both homogeneous land cover types and transitional vegetative zones. Many of the field test sites where visited in person and photographed on the ground.

PREPROCESSING

Preprocessing is a term used to specify those processing steps to which the digital data are subjected prior to clustering and classification. One type of preprocessing involves the mosaicking together of two Landsat scenes in their digital form. Mosaicking is performed when a study area is encompassed by two Landsat scenes, provided that the two scenes are adjacent to one another and provided that the scenes were imaged by Landsat on the same day. The mosaicked Landsat data can be generated so that the entire study area is covered by a single data set, thereby reducing the cost of digital processing.

Another type of digital preprocessing involves the repair of artifacts or inconsistencies in the data that are attributable to scanner malfunction rather than to information received from the ground by the satellite. Scanner malfunction can result in missing data or in the recording of false information ("noise" or "bad scan lines"). This type of preprocessing replaces missing or bad data lines with new values adjusted to those of the other scanners, and is referred to as radiometric correction.

A third type of preprocessing that is commonly performed is geometric correction, in which the Landsat digital data set is either registered digitally to a map base, or is at least rotated to north so that columns within the data are directly north-south. During the correction process skew, caused by the rotation of the earth under the satellite, is removed.

The radiometric and geometric corrections performed on the INTRISCA data are described in Appendix C, Digital Analysis of the Susitna Scene, and in Appendix D, Digital Analysis of the Anchorage/Eastern Scene.

DIGITAL ANALYSIS

The term digital analysis, in this context, refers to the steps involved in the generation of a classified Landsat image. These steps include: 1) training site selection, 2) clustering of training sites, 3) cluster evaluation and editing, 4) classification, and 5) identification of spectral classes and correlation of spectral classes with ground cover types (Figures 9, 10, and 11).

Basically, the purpose of digital image classification is to group a large number of pixels of similar reflectance values into a smaller number of meaningful categories that can be related to resource features.

Two Landsat CCT's were used in the project. One was called the Susitna Scene and the other was called the ANCHOR.EAST Scene. Digital analysis of each scene is described below.

ANCHOR.EAST Scene

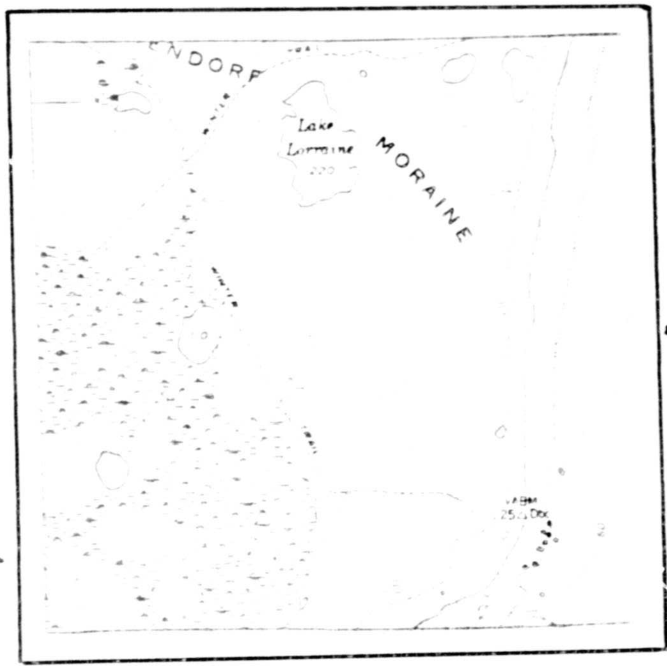
Training site selection is a process in which areas that have been identified as containing a single land cover type, either through photointerpretation or through field work, are delineated on the digital data. The areas within those training sites are then submitted to a statistical clustering program on the computer; the clustering program develops statistics (means, variances) that numerically describe the characteristics of each training class. The training statistics are in turn used by the classification program on the computer, along with the preprocessed Landsat scene in its digital (CCT) form, to identify pixels with similar spectral reflectance characteristics. These spectral classes result from the computer program's comparison of the characteristics of each picture element to the characteristics of the training statistics, then assigning that picture element to the training statistic it most closely resembles. Once the computer has assigned each picture element to a class, a new data set is created; this new data set is referred to as a classified image.

The classified image is then evaluated and the individual classes that comprise it are identified. This identification process can be performed in a variety of ways, depending upon the image analysis facilities available, but it is becoming more and more common to use a computer with a video display for the evaluation of spectral classes. The type of video display utilized for this purpose is part of a computer system, and enables the image analyst to display each component of the classified image one at a time or in combination with other classes. Field data and aerial photography (such as U-2 photography) are used by the analyst during this class identification/evaluation process: with the class displayed, the analyst compares the displayed

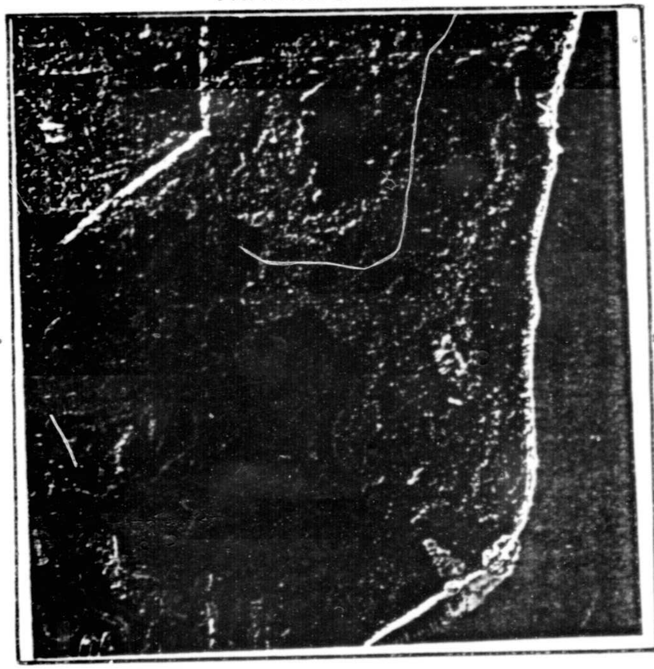
STEPS IN DIGITAL ANALYSIS

FIGURE 9. STEPS IN DIGITAL ANALYSIS

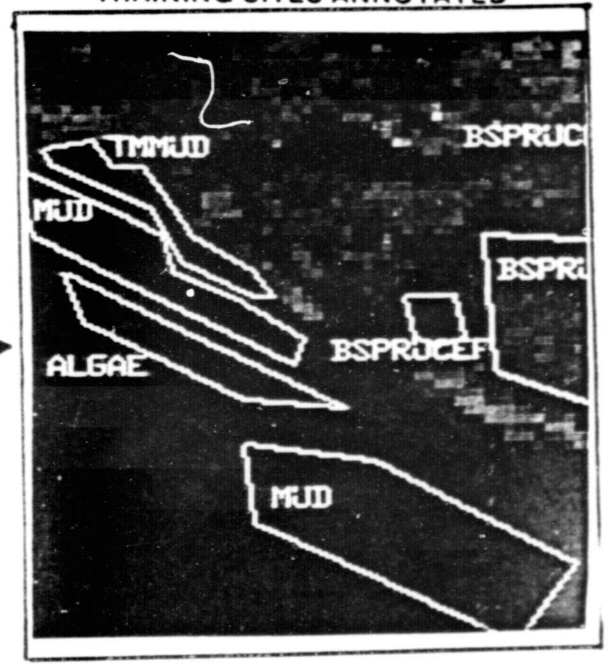
SELECTION OF TRAINING SITE AREA



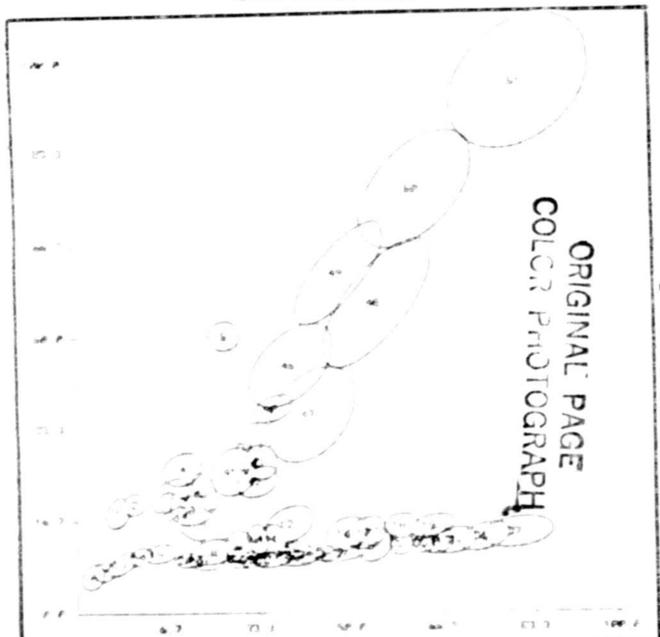
COLOR INFRARED AERIAL PHOTOGRAPH OF TRAINING AREA



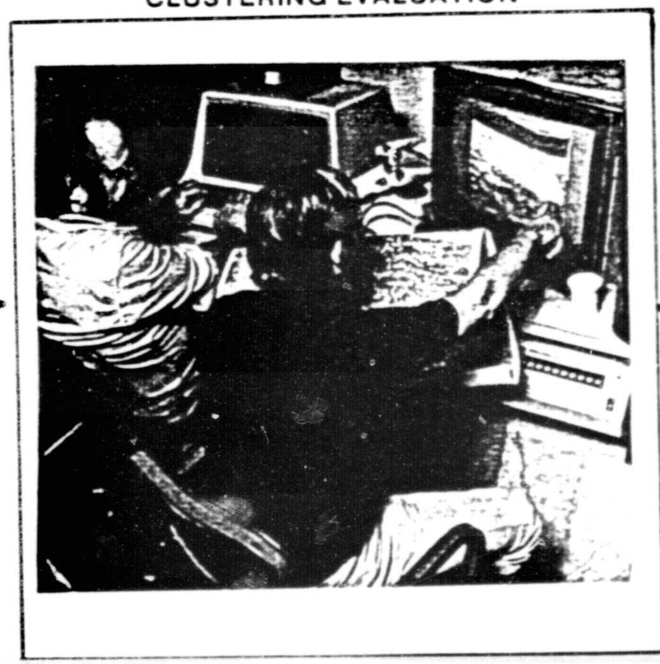
RAW LANDSAT DATA WITH TRAINING SITES ANNOTATED



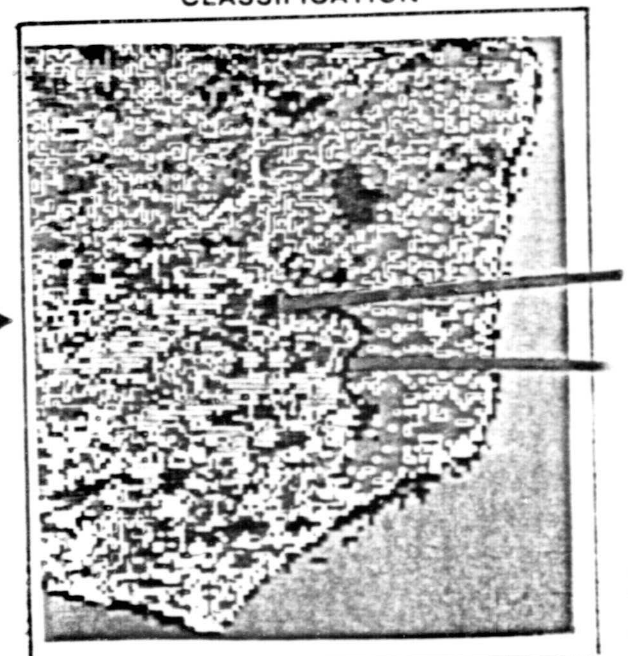
CLUSTERING



CLUSTERING EVALUATION

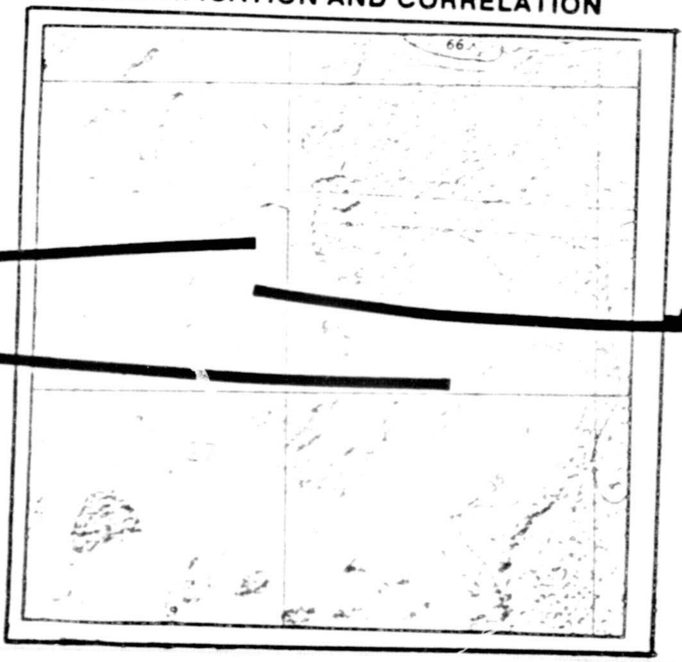


CLASSIFICATION



The approach used in developing a land cover classification for the project area is called a supervised classification. As land managers, we have land-use and land-cover information classes to deal with. We also have spectral reflectance classes to deal with that mean something to a computer. All classification procedures seek to bring together the two (land-use/land-cover and spectral reflectance classes) in a meaningful way. One such approach in accomplishing this is a supervised classification, in which land-use/cover classes are delineated on aerial photographs and maps and which uses the pixels included in there training sites to define spectral classes. The training sites consist of only one land cover information category and are as homogeneous as possible. All pixels occurring in a particular training site are grouped into one spectral class. These pixels are then used to create statistics files and produce cluster diagrams. After evaluating the statistical data, evaluations can be made. What is happening is that spectral space is subdivided into land cover information classes. Sometimes, spectral reflectance values are similar for two different land cover information classes and additional processing techniques are required to separate the two similar spectral classes into separate information classes. After cluster evaluation the classified pixels are mapped out in geographical space and their position is correlated with known land cover conditions. Accuracy evaluations can be statistically run to determine the accuracy of the classification. The final product is the land cover map. It is important to note that once a spectral class has been identified to consistently represent land cover information the spectral information is no longer important. Spectral data is a means to an end, the end is land classification.

IDENTIFICATION AND CORRELATION



LAND COVER MAP

INTRISCA

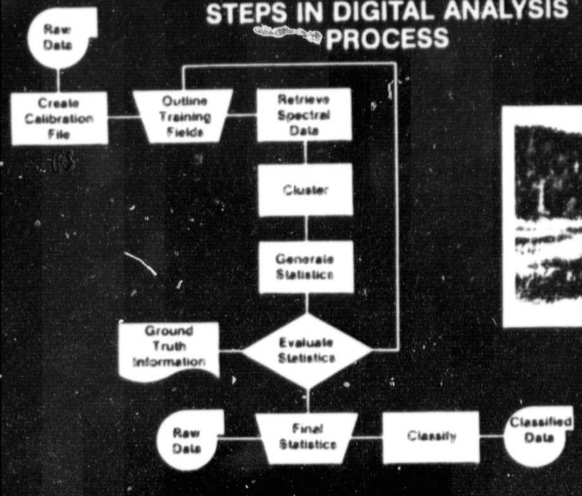
INTEGRATED RESOURCE INVENTORY FOR SOUTHCENTRAL ALASKA

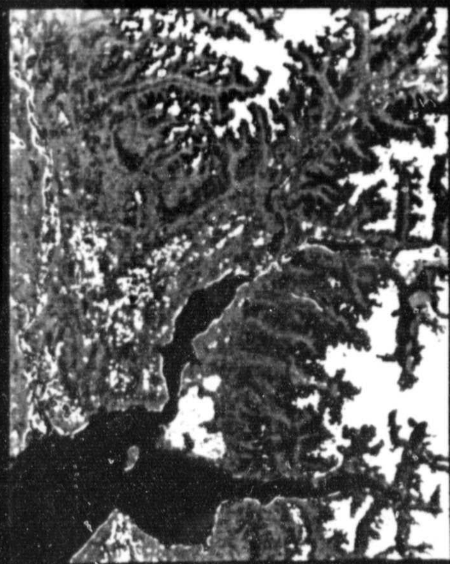
Raw Landsat Scene of Anchorage Area

State and local governments of the Cook Inlet region of Alaska, in cooperation with NASA, are developing a remote sensing demonstration program for an integrated resource inventory for Southcentral Alaska (INTRISCA) to meet their resource management objectives and information needs, and to cooperatively acquire the knowledge needed for the planning and management of land and water resources. An efficient method for obtaining this information is by using remote sensing techniques.

Previous work has been completed in the development of a Landsat land cover inventory of the study area through the Southcentral Alaska Water Level B Study. Products from this analysis will be modified (below) and enhanced so that they can be evaluated by agency participants and used to demonstrate the feasibility of a regional land cover inventory. Following this evaluation, new classification work will be undertaken to produce a land cover data set that is more recent, more specifically related to individual agency needs, and which can provide a comprehensive training experience for agency personnel.

STEPS IN DIGITAL ANALYSIS PROCESS





Stratified Water Resources (Level B) Classification

Eagle River Test Site

Land Cover Legend

- Coniferous Forest
- Deciduous Forest
- Deciduous Forest Wetlands
- Mixed Forest Wetlands
- Mixed Rangeland
- Grasslands
- Alpine Tundra
- Mudflats
- Barren Land
- Marsh
- Deep Water
- Shallow Turbid Water
- Commercial Industrial
- Residential — High Density
- Residential — Low Density
- Snow Ice Clouds

Participating Agencies

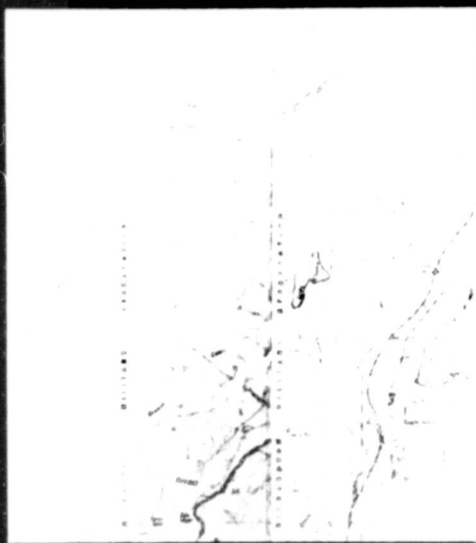
Municipality of Anchorage
Matanuska — Susitna Borough
Kodiak Island Borough
Alaska Department of Natural Resources
Alaska Department of Fish and Game

WRAP NASA

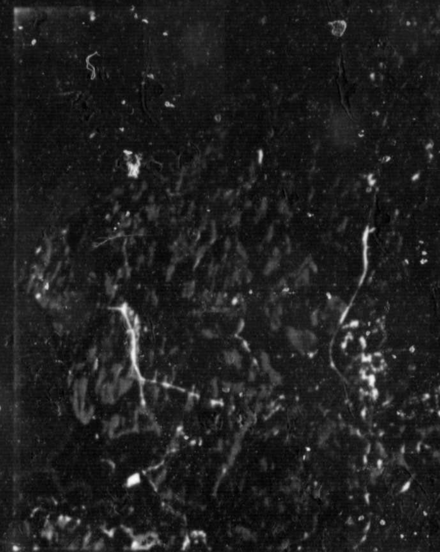
FIGURE 10. Integrated Resource Inventory for South Central Alaska

LAND COVER INVENTORY USING SATELLITE DATA

INTEGRATED RESOURCE INVENTORY FOR SOUTHCENTRAL ALASKA



Ancillary source materials include U.S.G.S. topographic maps utilized as base maps for recording of ground truth data and for the location of a ground control network.



Photointerpretation of color-infrared photography provides the basis for identification of spectral classes and location of training sites of known land cover categories for supervised clustering.

EAGLE RIVER TEST SITE

COMPUTER-AIDED ANALYSIS OF LANDSAT DIGITAL DATA

The Integrated Resource Inventory for Southcentral Alaska (INTRISCA) is part of an Applications Systems Verification and Transfer (ASVT) project. State, federal and local agencies of the Cook Inlet region are working in cooperation with NASA to implement remote sensing techniques in the development of a resource data base.

The land cover classification (shown at right) was completed by Dr. P. Krebs and P. Spencer as part of the Southcentral Water Resources Study (Level B). The Bureau of Land Management and the University of Alaska Geophysical Institute are working jointly to provide land cover/land use information utilizing computer-aided analysis of Landsat digital data. As part of the ASVT, NASA is responsible for evaluating the Level B classification.

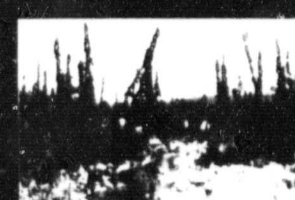
The Eagle River test site (shown at right) is a small subsection of the full scene classification completed to fulfill the Southcentral Water Resources Study (Level B). The original 43 spectral classes have been grouped into 16 land cover categories. Acreage summaries for any user specified area can also be obtained from the classified data.

Participants:
Municipality of Anchorage
Matanuska-Susitna Borough
Kodiak Island Borough
Alaska Department of Natural Resources
Alaska Department of Fish and Game

Land Cover Legend

Coniferous Forest	Barrens
Deciduous Forest	Marsh
Deciduous Forest/Wetlands	Deep Water
Mixed Forest/Wetlands	Shallow/Turbid Water
Mixed Rangeland	Commercial/Industrial
Grasslands	Residential-high density
Alpine Tundra	Residential-low density
Mudflats	Snow/Ice/Cloud

Aerial View



Marsh (Black Spruce)

Deciduous Forest

NASA
National Aeronautics and Space Administration

FIGURE 11 LAND COVER INVENTORY USING SATELLITE DATA

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computer class with the ground cover types seen on the photography and field data for the same location. Multiple geographic locations of the same computer class provide varied contexts within which to evaluate that class.

Once the computer classes have been identified, they are correlated with ground cover types, so that each computer class is assigned to one of the categories in the land cover classification scheme that was devised at the onset of the project. Concurrently, confusion that has occurred between spectrally-similar land cover types is noted for use in post-processing. The classified image is then ready for post-processing.

SUSITNA Scene

In supervised classification, the analyst selects areas that are spectrally homogeneous for each resource category. Because of variations in spectral characteristics of land cover types, more than one training area is usually selected for each land cover category. Training statistics, including the mean brightness value within the training area, variance about the mean, and the covariance between data channels are calculated for each training area. A clustering technique is used to identify a unique number of spectral classes within each training area.

The training areas were located on the Landsat data and all pixels within the training areas were clustered into a large number of spectral classes. A line printer map of each training area was compared with color infrared photographs and each spectral cluster was assigned to one the 17 ground cover classes. The statistics for all spectral clusters were used to calculate a statistical measure of the separability between spectral clusters in multidimensional space. The separability statistics and the interpreted cover class for each spectral cluster were then used to determine which spectral clusters could be combined.

The training area statistics and the Landsat data were input to a maximum likelihood classifier. Evaluation of initial results indicated confusion between such features as mudflats and the central business district. The Landsat digital data had to be stratified to remove the confusion and to create separate land cover classes. The spectral clusters were then displayed on a color terminal. Using aerial photographs, ground data, and other supporting data, the analyst identified the land cover types associated with each spectral cluster. In the example shown (Figure 12) fifty-one spectral clusters were identified in the sample data. Using this approach to derive training statistics, it was assumed that the sample data represented all of the cover types in the area. It was further assumed that each major cover category (deciduous, coniferous, mixed forest, etc.)

FIGURE 12

Position of Information Classes in Spectral Space

(Cluster Diagram on Page 48)

Landsat has four (4) channels; however, one cannot imagine four-dimensional space in graphical terms. By using two channels, a two-dimensional representation of spectral space can be produced. In Figure 12, Channel 2 corresponds to Band 5.(0.6-0.7 microns) and Channel 3 corresponds to Band 6(0.7-0.8 microns). Spectral classes tend to group in a triangular shape beginning in the lower left corner and spreading to the upper right. Various types of land cover spread out along the horizontal axis (conifers, mixed forest, deciduous forest, grasses). This is because most types of vegetation are equally low in red light reflectance (Channel 2) and very different in infrared reflectance (Channel 3). Along the 45° diagonal axis (lower left to upper right) the spread of water classes, barren areas, snow, ice and clouds occurs. For example, a tree leaf may reflect only 10 to 15 percent in the green portion of the spectrum, and as much as 40 to 50 percent in the near infrared. Wet soil produces a dark tone (low reflectance) and dry soil produces a light tone. Spectral reflectance is the ratio of reflected energy to incident radiation as a function of wavelength.

95.0% CONCENTRATION ELLIPSES FOR BANDS 3 AND 2
SUPERVISED STATS FOR SUSITNA SCENE

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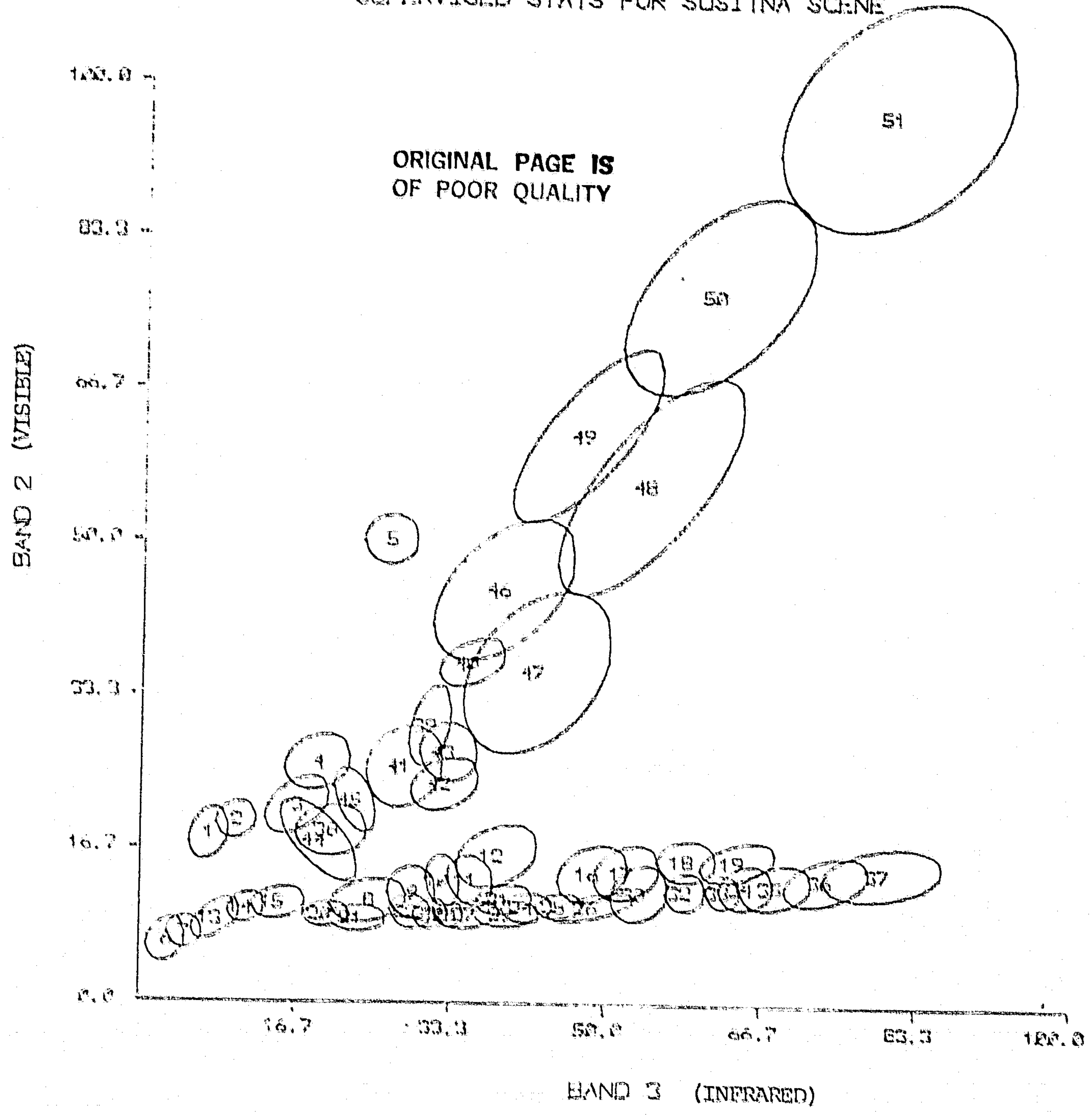

A two-dimensional plot is shown.
Each number represents the
location of a mean, while the
circle is a graphic portrayal of variance.

FIGURE 12. CLUSTER DIAGRAM

would be represented by at least one spectral cluster and that each spectral cluster would represent only one cover type.

A mean brightness value and its variance for each spectral band and a covariance matrix was calculated for each spectral cluster. These statistics were used in a maximum likelihood algorithm to classify each picture element into one of 51 cluster classes. Color infrared photographs and field data were used to assign each cluster class into one of seventeen land cover classes. The data were color encoded and recorded on film with both a film recording device and a Dunn camera system.

EVALUATION OF SPECTRAL CLASSES

Following classification, a series of four User Evaluation Workshops were conducted at Ames. The first of these four-day workshops was attended by Lee Wyatt from the Mat-Su (Matanuska-Susitna) Borough and by Tony Burns, the Instate Coordinator, who attended the entire series of workshops. The second of the workshops was attended by Peggy McNees of the Planning and Classification Section of Alaska State Department of Natural Resources (DNR); the third, by Merlin Wibbenmeyer of DNR/Forestry. The fourth workshop was conducted with and for Tony Burns, and focused upon Anchorage and other urban areas, as well as coastal wetlands under the jurisdiction of the Municipality of Anchorage. The objective of each of these workshops was to provide an opportunity for agency personnel to identify the spectral classes resulting from the classification of both 1978 scenes and to evaluate the classifications as a whole, using the IDIMS display as a tool. Since each of these agency personnel had expertise in different types of land cover, and in evaluation of most of the areas of interest that comprised the study area (such as Point McKenzie, the Eagle River Valley, Big Lake, and the Palmer/Wasilla area). Vegetation types -- in particular, forest and wetland cover types --and urban land cover types were carefully examined and evaluated in these and other areas using U-2 photography and field data as ground information. Available specialized land cover/land use maps were also consulted in evaluating the spectral classes, particularly in Anchorage and in the coastal wetland areas on the north side of Turnagain Arm.

POST-PROCESSING

Post-processing is a general term that refers to any digital processing that is performed after classification. Geometric correction, mentioned in the Preprocessing section, is sometimes performed on the classified image rather than on the original Landsat data in order to reduce the time and cost

required for the correction. Stratification that is performed in order to refine a classification and to reduce confusion between spectrally-similar land cover types is also referred to as a part of post-processing. The terms "grouping" and "smoothing" specify two additional types of post-processing that may be performed on a classified image.

Stratification, when performed in order to refine a classification, involves the digital separation of some geographic areas from surrounding portions of the digital classified image. This separation is effected through the drawing of digital lines around the area to be delineated; the lines are drawn either with a digitizer or with a cursor on a computer video display of the type described previously. Classes within the area that were separated or "lifted out" are then renamed from one computer category to another. The need for this type of stratification arises when land cover types are spectrally similar: two or three land cover types reflect light to the same degree, so that they look alike to the sensors aboard Landsat. Light grey bare rocks, for example, look the same as light grey pavement to the satellite because both reflect light similarly. If the classification scheme seeks to identify urban streets and paved areas, it is therefore necessary to digitally separate the urban area from surrounding natural areas containing bare rock, by stratifying. The same is true in classification schemes that include the distinction between shrub/grass tundra and occurrences of shrubs and grasses in lowland areas: stratification to separate altitude-dependent vegetative communities is common practice and, like geometric correction, may be performed either before or after classification. Appendix D deals with the actual stratifications performed on the INTRISCA classification. Additional information on the stratification process can also be found in Appendix E, regarding the stratification performed on the Level B Classification.

If stratification is performed for the purpose of refining the classification, grouping and smoothing processes follow the completion of the stratification. Grouping involves the aggregation of the computer (or spectral) classes into land cover categories that correspond with the classification scheme selected for the project. The grouping process is a simple assignment of one set of digital numbers to a second set of analyst-specified numbers. Smoothing is a process which, if used, follows grouping. Smoothing programs on the computer examine each picture element in the context of its neighbors and reassign categories into the predominant classes that surround them when isolated incidences of classes are located. The effect of smoothing is two-fold: it eliminates the salt-and-pepper effect found in most classified images, and it simulates a minimum mapping unit that corresponds to the neighborhood size. For example, a nine-picture-element neighborhood mimics a nine-acre minimum

mapping unit because each one-acre picture element is examined in the context of the eight acres (picture elements) surrounding it. The class reassignments that occur during smoothing then approximate the class assignments that would result from field work that classified land cover in nine-acre blocks or parcels. A description of the grouping and smoothing performed on the INTRISCA classification can be found in Appendix C, Digital Analysis of the Anchorage/ Eastern Scene.

OUTPUT PRODUCTS

Following the completion of all post-processing, the classified image is ready for the generation of output products. The type of output products available from a classification is dependent upon the resources at the image processing facility. Line printer maps or maps from an electrostatic printer/plotter (in which computer classes are represented by symbols) and photographic products generated from a film recorder are two common types of output products. A third output product, frequently generated from classified imagery, is a tabular summary of picture elements by land cover class, converted into acreages per class and into the percentage of the classified image allocated to each computer class. (Figure 13 and Tables 5 and 6 illustrate some of the products produced for the INTRISCA project).

Various combinations of these types of output products may be generated for a single classification in order to meet the needs of participating agencies. Line printer and plotter maps can be generated at a variety of map scales, and selected geographic areas of interest from the same classification may be printed at different map scales according to user agency base maps. For example, the Eagle River area of the INTRISCA classification was printed at a map scale of 1:24,000 to correspond to existing base maps at that scale. By the same token, photographic negatives of the classification can be generated on a film recorder and subsequently enlarged to match specific map scales. Negatives of selected areas of the INTRISCA classification, for example, were photographically enlarged to scales of approximately 1:25,000; 1:250,000; 1:63,360; and 1:1,000,000 to correspond to the scales of existing maps for those areas. User agencies were also provided with negatives of photographic output products, enabling them to generate additional photographic enlargements as required.

The delivery of final output products to user agencies provides the necessary materials for them to quantitatively evaluate, or conduct a verification/assessment of, the classification accuracy.

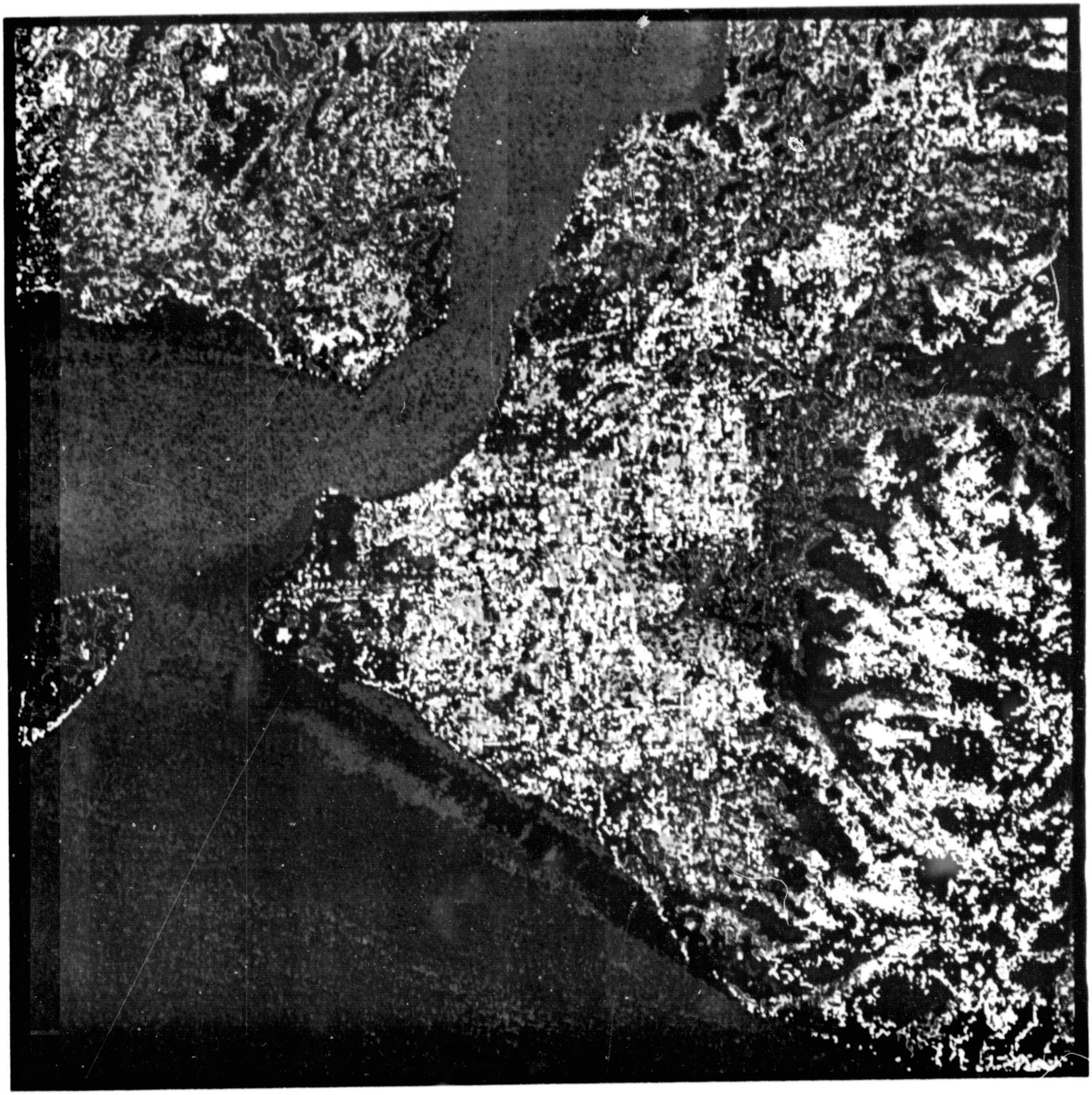

FIGURE 13. Example of INTRISCA Output Product
(Dicomed enlargement)

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TABLE 5. TABULAR SUMMARY OF PIXELS:
BIG LAKE TO SUSITNA RIVER

: N=1251,W=2255,S=2227,E=3121; **BIG LAKE to SUSITNA RIVER**

ENTER DATA

		PIXELS	ACRES	CLASS
CAT	1	65882	73788	sedimented water
CAT	2	30668	34348	clear water
CAT	3	155480	174138	shrub/moss bog
CAT	4	36202	40546	black spruce bog
CAT	5	9776	10949	grass
CAT	6	26306	29463	shrub
CAT	7	100597	112669	conifer
CAT	8	226438	253611	mixed forest
CAT	9	160428	179679	deciduous
CAT	10	31464	35240	barrens
CAT	11	1691	1894	alpine tundra
CAT	12	4	4	glacier
CAT	13	5	6	snow
CAT	16	690	773	commercial/industrial
CAT	17	231	259	transportation facilities
CAT	18	586	656	high density residential
CAT	19	508	569	low density residential
CAT	21	103	115	commercial
	TOTAL	847059	948706	

NOTE: Classes with pixel count of 0

are not listed by this program.

PIXEL COUNT

FROM IBM-360

1978 DATA - SUSITNA SCENE

(SMSUS)

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OF POOR QUALITY

TABLE 6. TABULAR SUMMARY OF PIXELS FROM IDIMS

PIXEL COUNT — BIG LAKE to SUSITNA RIVER

SYSUS

TOTAL COUNTED= 847254 NOT COUNTED= 0

CLASS	COUNT	FRACTION	CLASS NAME
0	0	.00000	background
1	65882	.07776	sedimented water
2	30668	.03621	clear water
3	155480	.18355	shrub/moss bog
4	36202	.04274	black spruce bog
5	9776	.01154	grass
6	26306	.03105	shrub
7	100597	.11873	conifer
8	226488	.26732	mixed forest
9	160623	.18959	deciduous
10	31464	.03714	barrens
11	1691	.00200	alpine tundra
12	4	.00000	glacier
13	5	.00001	snow
14	0	.00000	cloud
15	0	.00000	shadow
16	690	.00081	commercial/industrial
17	231	.00027	transportation facilities
18	585	.00069	high density residential
19	508	.00060	low density residential
20	0	.00000	central business district
21	103	.00012	commercial
22	0	.00000	background

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PIXCOUNT from IDIMS SYSTEM

1978 DATA

SUSITNA SCENE

(SMSUS 1251 2255 977 867)

CHAPTER V
SUBPROJECTS

In addition to producing a general land cover classification and map of the project area, several of the participating agencies had agency-specific projects which were designed to evaluate the usefulness of remote sensing techniques to specific problems. These projects included:

- Road Network Mapping
- Sea Surface Circulation Pattern Mapping
- Integration of Landsat Digital Data into a Geographic Information System
- Floodplain and Landform Mapping
- Urban Land Use Mapping

ROAD NETWORK MAPPING

One-dimensional edge enhancements performed on the IDIMS system were used by Matanuska-Susitna Borough for identifying road network patterns. Because of recent and very rapid growth within the Borough, planners wanted to know where all the new subdivisions were and where all the new roads were located. By utilizing this enhancement procedure, lineal features are optimally enhanced. Roads, railroads, powerlines, pipelines, seismic survey lines, and other linear cultural features can be differentiated through analysis of different MSS single-band or multi-band photo products derived from enhancement techniques on IDIMS. Technical documentation describing this procedure is contained in Appendix I. A set of computer generated photographic products were developed and provided to the borough for their use and application.

SEA SURFACE CIRCULATION MAPPING

Varying degrees of knowledge about water clarity, depth, circulation patterns, suspended sediment load, algae distribution, etc. can be derived from both raw and enhanced Landsat imagery. As part of the demonstration project, NASA enhanced four of the Landsat MSS bands to describe the meaning of reflectance values of water. Interpretation of color enhanced Landsat single channel images could provide useful information about circulation conditions in Upper Cook Inlet. The Alaska Department of Fish and Game, Matanuska-Susitna Borough and Municipality of Anchorage were participants in this subproject. Mr. Dave Burbank of the Department of Fish and Game conducted the analysis and interpretation of the data products supplied by NASA. Both the technical papers prepared by NASA and the interpretations conducted by Mr. Burbank can be found in Appendices G and H, respectively.

INTEGRATION OF LANDSAT DIGITAL DATA WITH A GEOGRAPHIC INFORMATION SYSTEM

Landsat digital data can frequently be enhanced when it is vertically integrated with other types of data such as topography, slope, soils, and landforms. This is best accomplished using a geographic information system (GIS).

Two test sites were selected for this demonstration; one in Anchorage and the other in the Matanuska-Susitna Borough. Both test sites were selected to demonstrate two different sets of applications.

Anchorage Test Site

A twenty-five square mile area in Anchorage was selected. This test site corresponded to an area where concurrent studies were being conducted by an independent consulting firm. The Hillside area of Anchorage presently does not have sewer systems, but instead relies on septic tanks. Increased growth in the Hillside area has brought about a need for higher densities; however, ground water pollution is considered a problem if densities increase. The consultant is therefore conducting a wastewater management plan for this ara. The use of a geographic information system will permit digitizing thematic data (geology, soils, drainage conditions, slope, etc.) and integrating these data sets with Landsat digital data to produce land use suitability/capability maps. The consultant is performing a similar study, but using manual techniques in addition to well log data. The results of both projects can thus be compared and an assessment of the results made.

Matanuska-Susitna Borough

The Wasilla/Big Lake area is a rapidly growing area and is presently used extensively for recreational activities. Both permanent and recreational homes are being built in the area. The physical area has also been previously glaciated, thus creating a landscape of lakes, moraines, and wetlands.

The Soil Conservation Service has recently completed a soil survey for this area and prepared land use suitability/capability maps (using a GIS approach). However, Soil Conservation Service land cover was photo-interpreted and collected on the ground as part of the soil survey. The purpose of the Landsat/GIS demonstration in this area was to assess the accuracy of land cover derived from Landsat with the land cover maps developed by SCS. Secondly, the project was intended to demonstrate that Landsat digital data in conjunction with collateral data could be used as a viable tool for determining land use suitability/capability and to compare the resultant land use suitability/capability maps with those of SCS. That is, do

land cover maps derived from the analysis and interpretation of Landsat imagery correspond favorably with land cover maps developed from field work, and do the resultant land use suitability/capability maps produced by SCS compare favorably with those produced as a result of this demonstration project. A favorable correlation would indicate that this approach could be utilized in an operational mode.

FLOODPLAIN AND LANDFORM MAPPING

The purpose of this subproject was to study and map the landforms within a corridor along select streams in the Susitna River Valley. The investigation utilized color infrared aerial photography, Landsat imagery, USGS topographic maps and aerial and ground verification procedures. The results of the project provided land managers with an initial data base to establish riparian management zones or buffer zones to protect fish and wildlife and their habitats from disturbance or damage. A secondary objective of the study was to compare the minimum size of floodplains and number of floodplain categories derived from aerial photography to that derived from Landsat imagery. This project was conducted by Mr. Kenneson G. Dean, Northern Remote Sensing Laboratory, Geophysical Institute, University of Alaska under a NASA/Ames Research Center Consortium Agreement for the Alaska Department of Fish and Game.

URBAN LAND USE MAPPING

The Municipality of Anchorage was particularly interested in investigating to what extent urban land use could be identified and mapped using Landsat imagery. Several hundred ground training sites were plotted and used to classify the Landsat digital data. Output products included Dicomed generated film prints and Dunn Polaroid prints of the urban area. These color-coded maps or prints were then checked against existing land use maps. This accuracy assessment is still going on. It is hoped that an acceptable level of accuracy is determined so that other Landsat imagery can be used to measure growth change, rate and direction. This process is called change detection, and if successful would provide the Municipality with a relatively inexpensive and rapid means of measuring urban growth and change.

APPENDIX A
INTRISCA PROJECT
AQUISITION OF IMAGERY

L. MORRISSEY

Landsat digital data in the form of computer compatible tapes and color composite photographic images (Figure 14) were used in the analysis of the Susitna Basin. Landsat color composites were used for delineation of environmental strata, the selection of training sites, and as a navigational tool during aerial overflights of the study region. The computer compatible tapes were used in the digital processing of the Landsat data.

Landsat scenes were selected on the basis of percent of cloud cover, season of the year, and orbital path. Complete coverage of the study region was obtained with portions of the following three Landsat scenes:

21288-20250	August 2, 1978
21288-20253	August 2, 1978
30175-20345	August 27, 1978

Two of these scenes (21288-20250 and 21288-20253) are within the same orbital path, and the third (30175-20345) is from an orbital path to the east. Computer compatible tapes were acquired from EROS (Earth Resources Observation Systems) Data Center.

Color-infrared photography (CIR) provided a necessary link between ground visits and the Landsat digital data with the development of photo-interpretation keys which allow the analyst to extrapolate information gathered during ground visits over larger areas. The CIR photography is primarily useful for collection of ground data and spectral class verification.

A search of available CIR photography was made at the U-2 Data Facility located at Ames Research Center. Flight lines of all CIR photography falling within the study region were plotted on 1:1,000,000-scale quadrangles (Figure 15). The photography was viewed eliminating those frames that had excessive cloud cover. Each of the participating agencies were given selected photographic coverage (Table 7) of areas they had designated high priority. NASA also maintained a duplicate set of photographs for evaluation of the classifications.

FIGURE 14. LANDSAT COLOR COMPOSITE

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COLOR PHOTOGRAPH

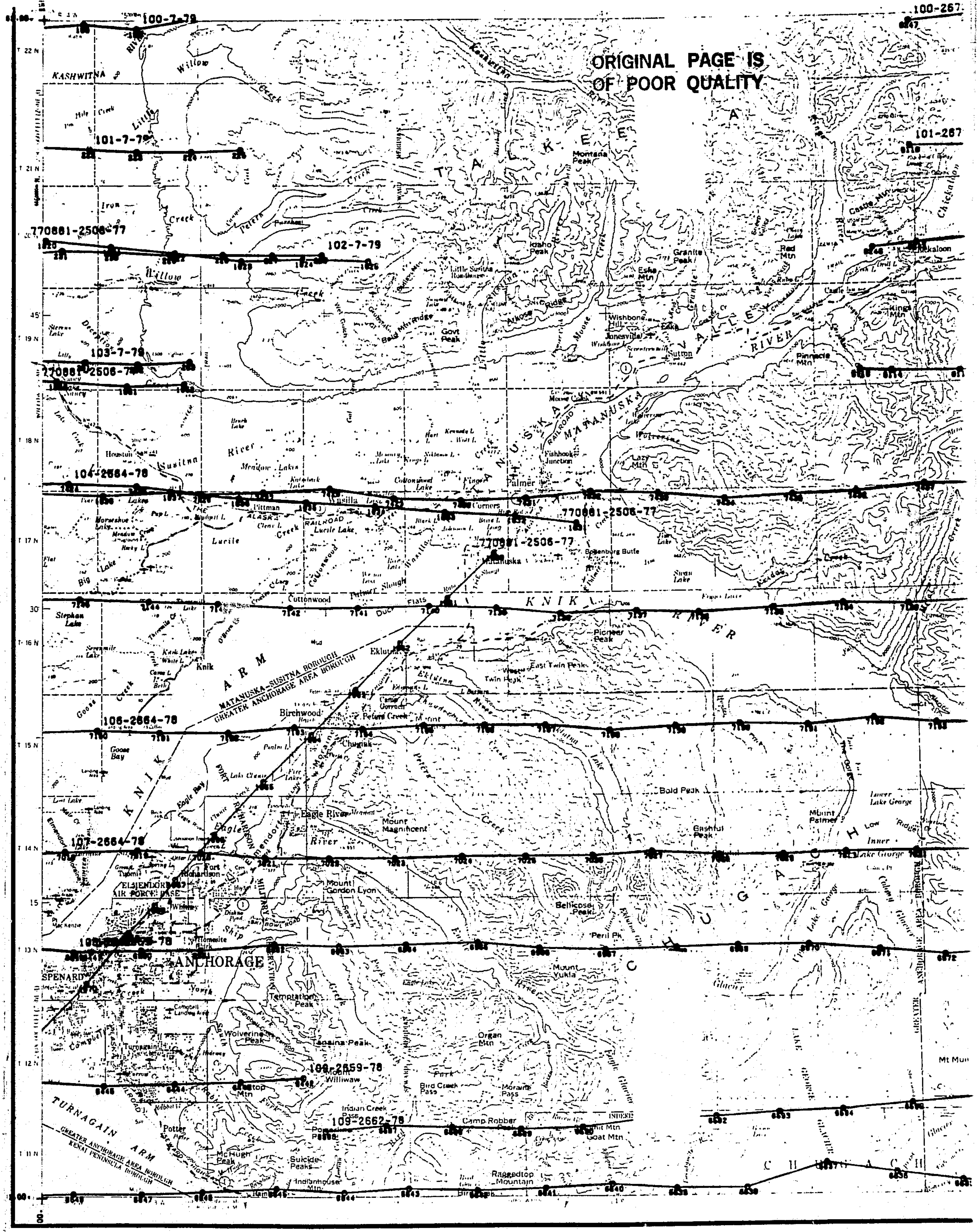

FIGURE 15. FLIGHT LINES ALL 1:60,000 CIR COVERAGE

Table 7

Distribution of CIR Photography

Agency	Flight line	Frames
Anchorage	78-115	6443, 6445
	78-119	7018, 7020, 7022, 7024
DNR-Forestry	74-104	9816, 9818, 9859, 9866, 9868, 9886, 9888, 9900
	77-088	5942, 5944, 5968, 5972, 5974
	78-119	7014, 7016, 7018, 7020, 7022, 7024, 7138, 7140, 7142, 7144, 7146, 7149, 7151, 7175, 7177, 7319, 7321, 7409, 7411, 7413, 7415, 7420, 7422, 7424, 7426, 7430, 7432
	78-115	6382, 6384, 6386, 6388, 6390, 6443, 6445, 6452, 6454, 6456, 6476, 6478, 6480
Mat-Su Borough	78-119	7138, 7140, 7142, 7430, 7432
	74-104	9866, 9868, 9886, 9888
	77-088	5942, 5944,
DNR-Land Resource Planning	77-088	5942, 5944, 5972, 5974
	74-104	9816, 9818, 9866, 9868, 9886, 9888
	78-119	7136, 7140, 7142, 7175, 7177, 7409, 7411, 7413, 7415, 7430, 7432
Fish and Game	78-115	6382, 6384, 6386, 6388, 6390, 6392
	74-104	9859
	78-119	7014, 7016, 7138, 7140 7142, 7149, 7151, 7430, 7432

APPENDIX B

INTRISCA PROJECT
GROUND DATA COLLECTION

Leslie A. Morrissey

The accurate classification of land use and land cover information with Landsat multispectral data requires the careful collection of ground data in selected areas of a study region. In the supervised clustering approach this ground data is utilized in the development of spectral statistics representative of informational land cover categories. Additionally, the ground data also provides the basis for evaluation and verification of the spectral classes. Ground excursions coupled with the recognition of spectral response on the aerial photos provides photo-interpretation training for state agency personnel.

In order to maximize the collection of ground data, personnel from each agency participated in the 1979 summer field season. Nine critical zones within the study region were chosen for collection of ground data during the short field season. Each agency was responsible for certain land cover categories within specific critical zones to avoid duplication and to successfully utilize the professional expertise of agency personnel. Agency assignments were as follows:

DNR-Forestry--Mainly forest, woodlands, some rangeland

DNR-Planning and Classification--Rangeland, wetlands, forests

Municipality of Anchorage--Mainly urban, some rangeland and forest

Mat-Su Borough--Agricultural and urban

Selection of Training Sites. Training sites selected for the collection of ground truth information should meet certain basic criteria. Most importantly, the training sites must encompass all known cover types, as well as all possible spectral variation within each cover type. The analyst must, therefore, be knowledgeable of the cover types which exist within the study region. The preliminary classification scheme (Table 8) for the INTRISCA project was devised to attain maximum detail with Landsat digital data while satisfying the needs of the state agencies.

The supervised approach requires the location of a number of sites of known land cover. These training sites must be

Table 8. INTRISCA Ground Truth Scheme

- 100 BARREN LAND
  - 110 Mudflats
  - 120 Bare soil
  - 130 Bare exposed rock
- 200 WATER RESOURCES
  - 210 Deep water
  - 220 Shallow/sedimented water
  - 230 Freshwater lakes and streams
- 300 AGRICULTURAL LAND
  - 310 Cropland and pasture
  - 320 Other agricultural land
- 400 URBAN
  - 410 Residential
    - 410.1 High density
    - 410.2 Low density
  - 420 Wooded residential
  - 430 Commercial/industrial/institutional
  - 440 Pavement/transportation
  - 450 Mobile homes
  - 460 Mixed (undifferentiated) urban
- 500 EXTRACTIVE INDUSTRY & NATURAL DISASTERS
  - 510 Strip mines, quarries, gravel pits
  - 520 Clear cuts
  - 530 Forest fire areas
- 600 NATURAL VEGETATION
  - 610 Rangeland
    - 611 Herbaceous meadow (grassland)
    - 612 Shrub
      - 612.1 Tall shrub (alder)
      - 612.2 Low shrub
    - 613 Mixed rangeland
  - 620 Forest
    - 621 Broadleaf
    - 622 Conifer
    - 623 Conifer/broadleaf
    - 624 Broadleaf/conifer
  - 630 Woodland
    - 631 Broadleaf
    - 632 Conifer
    - 633 Conifer/broadleaf
    - 634 Broadleaf/conifer
  - 640 Tundra
    - 641 Herbaceous tundra
    - 642 Shrub tundra
    - 643 Alpine tundra (mat and cushion)
- 700 PERENNIAL SNOW AND ICE
  - 710 Snow and Ice
  - 720 Glacier

Table 8. INTRISCA Ground Truth Scheme

uniform in spectral response and representative of a homogeneous cover or vegetative community. Homogeneity can include a uniform mix of species within a training site. For instance, a mixed forest with equal proportions of conifers and deciduous trees is considered homogeneous. Transitional areas such as ecotones or boundaries which grade into nearby cover types or along roads, should be avoided. (Procedures used for training site selection are shown in Table 9).

Training sites which are utilized in digital analysis must meet minimum size and shape considerations. Sites should be at least 10 acres for urban and other non-extensive cover types, 40 acres for natural vegetation , and a minimum of 5 acres in width. At least five training sites for each cover type should be distributed throughout the study region. In some instances, unique cover types may not meet minimum size requirements. However, these training sites can be utilized in the development of photo-interpretation keys.

Spectral reflectance values for each cover type can be affected by a number of landscape variables. Therefore, selection of training sites must encompass all possible variations for each cover type. Such factors include:

- Degree and aspect of slope
- Species (broadleaf vs. needles)
- Plant vigor and age
- Understory cover
- Soil moisture

A few examples follow which will illustrate spectral variation of vegetation based on differing landscape characteristics. For instance, a birch stand of similar age and size will appear much brighter spectrally than a pure birch stand of varying size despite an identical crown cover. Likewise, a stand of conifers on a north-facing slope in shadow will be much darker spectrally than the same stand on a lowland. Typical temperate grasslands have a high IR (infrared) response; however, if the soil is saturated, the spectral response becomes much lower. Many times the components of the overall cover will produce unexpected reflectance values. Often in marsh areas, the spectral response of the saturated soil will overwhelm the high IR response of the grasses and the overall spectral response will be low, similar to that of conifers.

Reflectance values of natural vegetation are affected by leaf or blade type. Broadleaf trees have much higher

TABLE 9

PROCEDURE FOR ESTABLISHING TRAINING SITES

PRE-FIELD STEPS:

1. Obtain stereo model prints (sets of 3 per location) of aerial photography to be used in the field with mylar overlay.
2. Scotch tape photo and mylar to sleeve. On mylar overlay indicate north arrow, frame number and fiducial marks.
3. Locate a number of homogeneous training sites for each landcover type (or spectral signature) on the center frame of the stereo prints on aerial photography. Sites should be distributed over entire test region.
   a. Locate sites in relation to prominent surface features which can be found in the field (roadways, intersections, creeks, power lines, railroads tracks, lakes, houses, etc.).
   b. Training sites should be at least 10 acres in size, preferably 40 acres. Avoid linear sites; at least 5 acres in width (40 acre field is roughly 1/4" x 1/4" 1:62,500 photo).
   c. Check for road access to sites. Will four-wheel drive be required?
   d. Concentrate training sites for maximum use of field time.
4. Outline each homogeneous training site on mylar over aerial photography. Assign a field number along side of boundary.
5. Transfer training site boundaries to topographic maps.
6. Delineate training site locations on maps and determine best route. (With an auto approximately 10 sites can be visited per day.)

FIELD WORK:

1. For each homogeneous training site outlined & referenced on an aerial photograph, fill out a ground truth data form from information readily available on topo maps and aerial photographs.
2. If on field examination, area selected does not meet criteria, reject area and select another.
3. Horizontal and vertical ground photos will provide a permanent record of each site.

reflectance values than needleleaf trees of similar crown density. Likewise, grasses are much brighter in the IR than sedges. The analyst must be aware of the cover types, spectral variation within each cover, and the interaction of landscape variables with vegetation to coordinate the collection of ground data for a supervised classification.

Delineation of Training Sites. Training sites should be delineated on mylar attached to a photo print and assigned a field number. Check for road access to each site if fixed wing aircraft are not to be utilized during the field season. Locating training sites in the field can often be quite a time consuming problem. To maximize time and effort, training sites should be located near prominent surface features (i.e., roads, creeks, lakes, power lines etc.) and should be concentrated whenever possible to cut down on travel time between sites. Clear cuts in forested areas often produce distinct vegetation boundaries in which training sites can be located on both sides of the boundary.

After training sites have been delineated on mylar, they should be referenced to the corresponding aerial photo and preliminary information which can be gleaned from the aerial photo or topographic maps can be completed on the ground data forms (Figure 16).

Ground Truth Packets. To familiarize agency personnel in the recognition of major vegetative species, a photo key was completed containing ground photos of major tree species along with written descriptions. An example of the photo key is shown in Figure 17. Ground truth packets also included U-2 CIR photography, U-2 flight summary reports, area and proportion diagrams (Figures 18, 19), guidelines for selection of training sites, data collection forms, and preliminary classification scheme.

Orientation of Agency Personnel. Prior to the beginning of actual gorund data collection, all state project team members participating in the field season attended a two-day orientation workshop. Data collection forms were discussed and training site selection was begun. One day was spent in the field to familiarize all participants with major vegetative species and most importantly, to standardize the completion of the data collection forms. The field trip proved invaluable for refining the land cover classification scheme.

Data Collection. Project team members accompanied a TGS analyst into the field the second week. The first three days, personnel from DNR-Planning and Classification and Forestry received instruction in data collection procedures and visited approximately 30 training sites. The fourth day

Field No.__________

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FIGURE 16. GROUND TRUTH DATA FORM

GENERAL

Observer__________ Date__________

Quadrangle__________ Latitude/Longitude__________

Locality__________

Photos Roll______ Frame______ CIR Frame and Date__________

PHYSIOGRAPHY (determine from topo map)

Elevation__________ Slope__________ Aspect N S E W

Position on Slope (Toe, Mid, Upper, Ridge)__________

Macrorelief Lowland Transitional Mountainous Landform__________

VEGETATION (circle one)

Level I Forest Woodland Shrubland Tundra Grassland Bog Aquatic

Level II__________ Level III__________

Height		Community	Dominant Species		
____	Overstory	______	1.______	2.______	3.______
____	Intermediate	______	1.______	2.______	3.______
____	Ground Layer	______	1.______	2.______	3.______
____	Surface Layer	______	1.______	2.______	3.______

Cumulative Vegetative Cover

1. 95 - 100% 4. 25 - 49%
2. 75 - 94% 5. 10 - 24%
3. 50 - 74% 6. 0 - 9%

Forest Crown Cover__________

__________ Uniform

__________ not uniform

Percentage Cover		Species according to dominance
____	Coniferous Trees	__________
____	Deciduous Trees	__________
____	Tall Shrubs (> 6 ft.)	__________
____	Medium Ht. Shrubs (2-6 ft.)	__________
____	Dwarf Shrubs (1/2-2 ft.)	__________
____	Prostrate Shrubs (< 1/2 ft.)	__________
____	Grass/Sedges	__________
____	Forbs	__________
____	Mosses & Lichens	__________
____	Bare soil	__________
____	Rock	__________
____	Water	__________
____	Litter ____ Other (specify)	__________

LAND USE (Circle one)

Level I Agriculture Residential Commercial/Industrial Level II__________

Soils: Sand Silt Clay Gravel Loam Stones Bedrock Peat

Soil Moisture: Dry Moist Saturated Standing water

COMMENTS: (over)

FIGURE 17. PHOTO-KEY FOR PAPER BIRCH

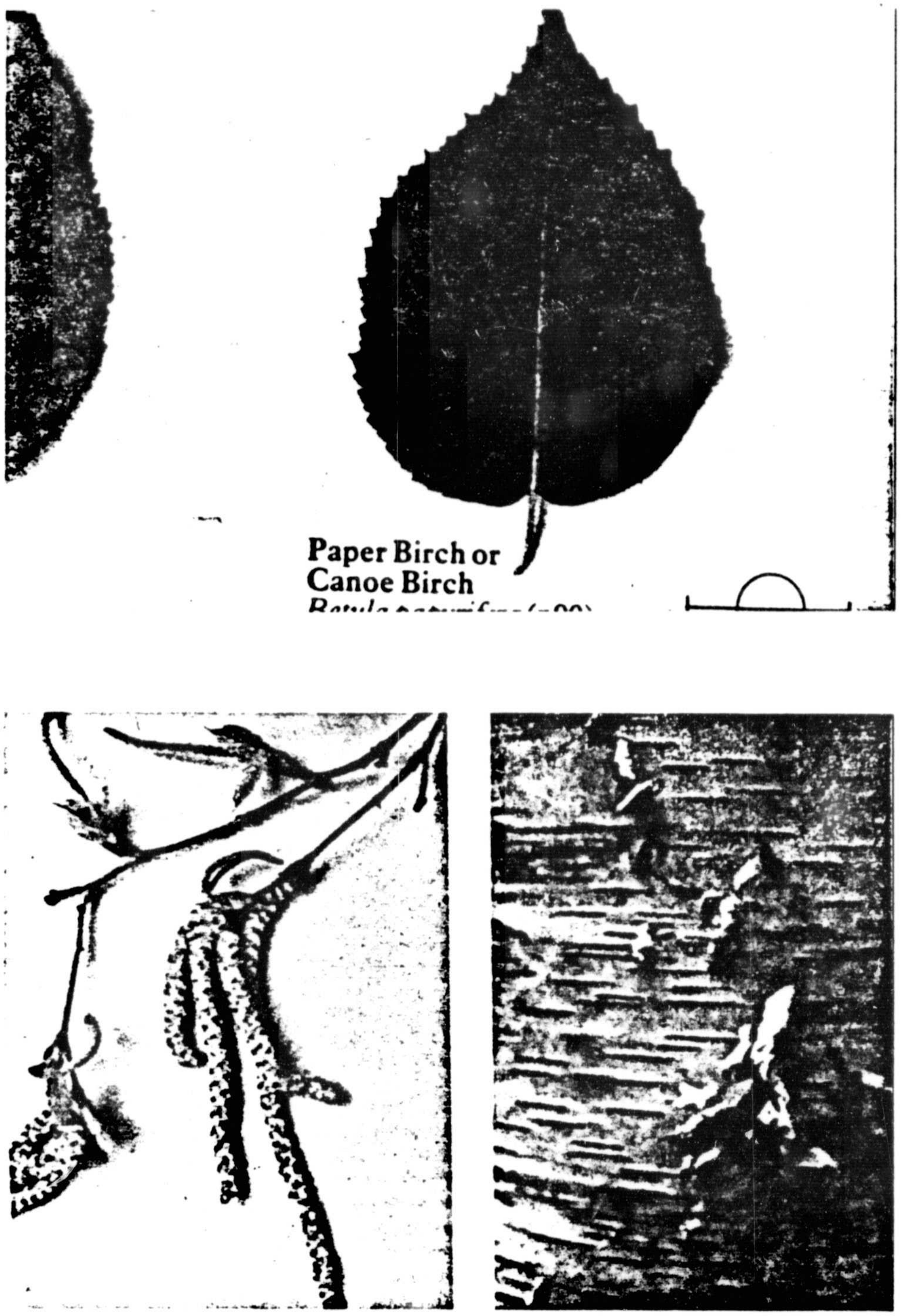
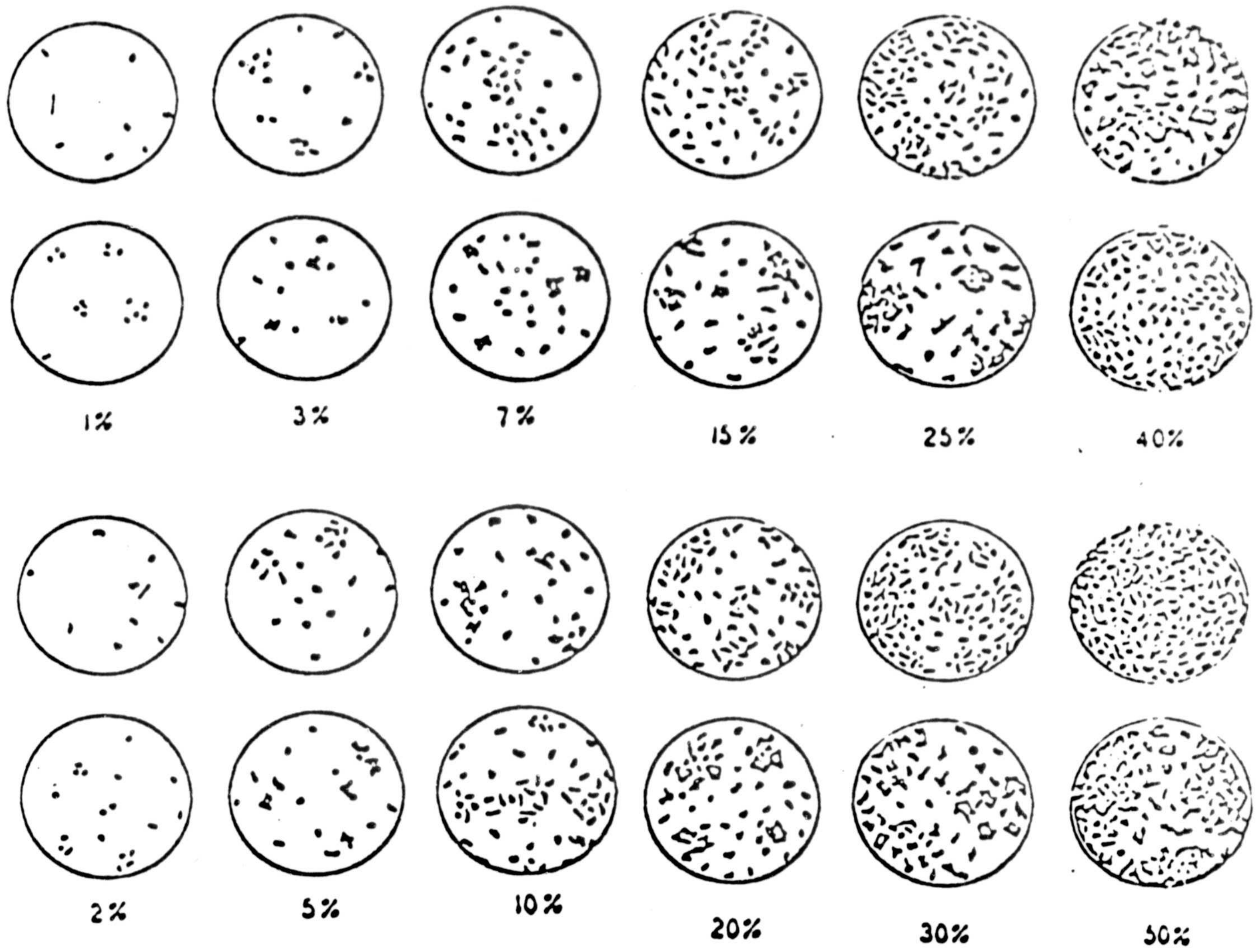
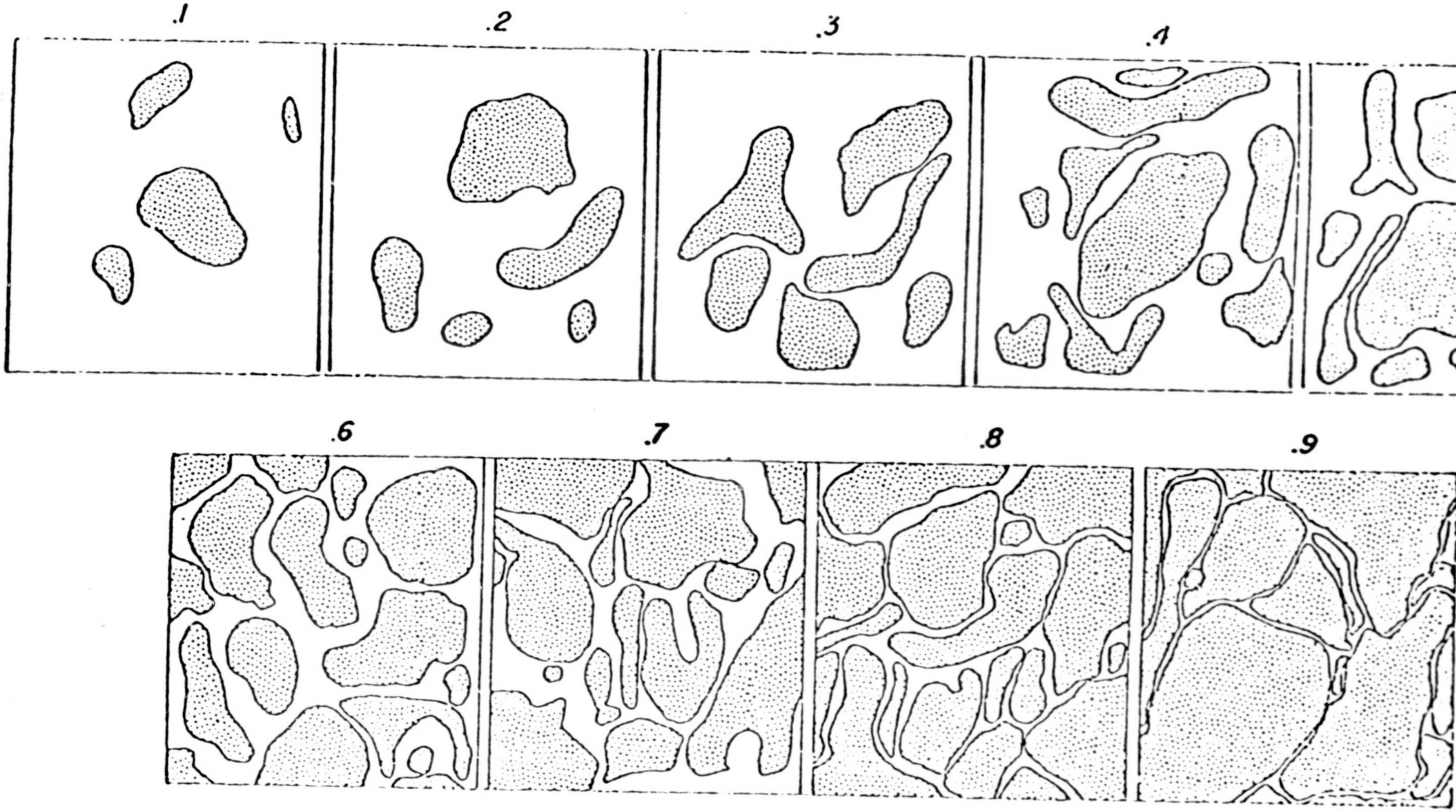


FIGURE 18. COMPARISON CHART FOR VISUAL
EXTIMATION OF PERCENTAGE COVER



Comparison charts for visual estimation of percentage cover. Adapted from Terry and Chilingar (1955).

FIGURE 19. COMPARISON CHART FOR ESTIMATION OR PERCENTAGE OF DELINEATION AREA AND PERCENTAGE COVER



Comparison charts for estimation of percentage of delineation area and percentage cover. Adapted from U. S. Forest Service, Region One, Range Management Handbook (1941).

was allotted to the collection of data for urban and agricultural training sites with planners from the Municipality of Anchorage and Mat-Su Borough. The final day required the use of fixed-wing aircraft for overflights to inaccessible areas within the study region. Trained in data collection procedures, each agency was requested to continue data collection throughout the summer. Each agency was requested to secure ground data for approximately 50 training sites.

At the beginning of each day, training sites were plotted on available maps and routes were determined. Ground truth forms were completed for each training site. The vegetation community is assigned to one of the land cover categories (Level I). Each successive (community) level is described with a listing of species by areal dominance. The percentage of areal cover of the individual cover components is very important in Landsat analysis. This refers to the overall cover if one were above the canopy looking down (tabletop view). The final assignment of each training site is largely dependent on the areal dominance of individual components.

Ground photographs provided a permanent record of each training site. A vertical shot records the specific ground cover components and a horizontal shot gives an indication of the general overall appearance characteristics of the vegetation. It's advisable to always include some object for scale.

When collecting site information by aircraft a team approach is advisable. One individual takes camera shots and the other records the location of the camera shot, vegetation type, and any other pertinent information on the CIR photography. Flight lines should be determined prior to actual flight time and plotted on topographic maps. The first flight line should overfly sites previously visited on the ground to correlate vegetative communities at ground level and overhead. Locate sites near prominent features for easy location.

Completion of Data Collection. With completion of the field season, copies of all ground truth forms, location of training sites, and ground photos from each agency were sent to NASA for evaluation and editing in preparation for upcoming workshops. Tallies of the training sites were made by agency and for each cover type. The total number of training sites visited by each state agency are as follows:

DNR-Forestry	56
DNR-Planning and Classification	30
Municipality of Anchorage	132
Mat-Su Borough	46

Certain land cover categories were found to be lacking a sufficient number of training sites (tundra, water, tidal marsh). These categories were supplemented with training sites delineated through photo-interpretation of U-2 and low altitude natural color photography. Availability of U.S. Dept. of Agriculture, Soil Conservation Service (SCS) data will provide additional ground data information for evaluation of the classification. (SCS was also conducting a river basin and soil mapping project in the study area.

The classification scheme evolved during the field season to encompass cover types not anticipated prior to the field season. During clustering of the multispectral data, the analysts will strive for additional cover information relating to density, species, understory: information which was not specifically trained upon during clustering.

The usefulness and quality of the training sites selected will greatly affect the accurate classification of land cover categories in the study region. Although a great number of training sites were visited during the field season, there is no way to verify that the training sites do indeed encompass all possible spectral variations in the Landsat scene. Therefore, the supervised statistics will be merged with statistics generated during unsupervised clustering of the full Landsat scene. Unique land cover categories will be extracted in the unsupervised clustering.

The training sites will be utilized in the upcoming workshops involving state agency personnel. It is felt that agency involvement in every step of the digital analysis process will give agency personnel a clear understanding of the advantages, as well as limitations, of Landsat digital data. A photo-interpretation key and instructional materials are also being prepared for distribution to agency users.

APPENDIX C

INTRISCA

DIGITAL ANALYSIS OF SUSITNA SCENE

L. Morrissey

TRAINING SITE SELECTION WORKSHOPS

Following completion of ground data collection in the summer of 1979, a series of three-day workshops was held at Ames Research Center to delineate training sites on the IDIMS COMTAL display. T. Burns, Municipality of Anchorage, provided training sites for the Anchorage urbanized area, Eagle River valley, and sections of the Mat-Su Borough. R. Loeffler, Department of Natural Resources-Planning and Classification, and M. Wibbenmeyer, Department of Natural Resources-Forestry, delineated training sites throughout the study region. Although unable to attend a workshop, training site information gathered by E. Wycoff, Mat-Su Borough, was also incorporated. A total of 264 training sites were delineated on the COMTAL display by participating agency personnel with the following agency breakdown:

DNR-Forestry	56
DNR-Planning and Classification	30
Municipality of Anchorage	132
Mat-Su Borough	46

Utilization of the COMTAL display for training site selection facilitated refinement of training sites proposed during visual examination of the MSS data. Training site boundaries were often extended when the spectral categories encompassed an adjacent area, while spectral anomalies occurring within proposed site boundaries were eliminated during actual delineation of boundaries. Thus, visual examination of the MSS data maintained spectral homogeneity within training sites. In addition, agency users were able to associate spectral signatures with resource categories by visual examination of the MSS data. Agency involvement in this phase of the project was beneficial for users who were able to learn by participation.

Training sites were duplicated on overlapping portions of the two Landsat data sets used in the analysis. Examination of the number and distribution of training sites by land cover type revealed certain discrepancies. Various cover

types were not adequately represented. Specifically, in the uplands alpine tundra, bare rock, snow and ice were overlooked, while floodplain barrens and sedimented water in the lowlands needed additional training. These training sites were incorporated by project analysts through photo interpretation of available CIR photography. In addition, some cover types had too few training sites and/or too few pixels for cluster analysis. For example, only one training site for aspen forest was found. Clustering of cover types with too few pixels often produces a cluster with extremely high or extremely low variances--both extremes are unsatisfactory for a maximum likelihood classifier and were eliminated in the statistical editing process. Training site information by cover type for the Susitna scene is given in Table 10.

COMPUTER SYSTEMS USED IN THE ANALYSIS OF THE SUSITNA SCENE

Analysis of the Susitna scene utilized several computer systems available at Ames Research Center. The EDITOR (ERTS Data Interpreter and TENEX Operations Recorder) software package developed by the Center for Advance Computation (CAC) provided the mainstay for interactive image analysis. The EDITOR package is available on the TENEX PDP-10 at the computer facility of Bolt, Beranek, and Newman (BBN) in Boston and is accessed through telephone lines via the ARPA (Advanced Research Projects Agency) Network. Initial training site selection and evaluation of the spectral classes were completed using the IDIMS (Interactive Digital Image Manipulation System) software and COMTAL display implemented on an HP 3000 computer at Ames. Large-scale clustering and classification required the use of the ILLIAC IV, also on the ARPA Network. Preprocessing, reformatting, and generation of output products were completed using the IBM 360/67. Access to several computers allowed use of the most efficient system for each specific processing task.

ACQUISITION AND PREPROCESSING OF LANDSAT DATA

Landsat scenes were selected on the basis of cloud cover, season of the year, and orbital path. Complete coverage of the study region was obtained with portions of three Landsat scenes. Two of these scenes (21288-20250 and 21288-20253) are within the same orbital path and the third (30175-20345) is from an orbital path to the east. Computer compatible tapes were acquired from EROS (Earth Resources Observation Systems) Data Center.

Preprocessing of the data prior to classification included removal of bad data lines, geometric correction, and rotation

TABLE 10

INTRISCA TRAINING SITE SELECTION 11/26 - 12/7

Label	Description of Land Cover Category
SANDEXT	Sand extraction
DECID	Deciduous forest; 50% tree cover; includes any decid mix
WETLAND	Tidal marsh (carex species)
MIXWOOD	Deciduous and coniferous mixed woodland
SEDWATER	Sedimented water/also shallow
WATERCL	Clear water (inland lakes)
BSPRUCEB	Black spruce bog 10-25% tree cover
AIRPORT	Airports
RURALRES	Rural residential -- large lots
GRASS	Agriculture, golf courses for ANCHOR.EAST, and grassland for SUSITNA
SPRUCEB	Black spruce forest (without bog)
TUNDRA	Grass and shrub (alpine) tundra
SHADOW	Mountain shadows; north-facing slopes
BARREN	Soils, bare ground
SCHOOL	School site (Anchorage)
RESIDENT	Residential
COM	Commercial
WETLAND	Upland sedge marsh
ROCK	Bare exposed rock
CONIF	Coniferous forest
ASPEN	Aspen forest
SHMOSSB	Shrub/moss/sedge bog
SHRUB	Shrubs -- alder and willow
DECCON	Deciduous trees in majority, coniferous forest in minority
CONDEC	Coniferous trees in majority, deciduous forest in minority
BULRUSH	Bullrushes in tidal marsh (Palmer Flats)
BIRCH	Birch forest
ICE	Ice and snow
CLOUD	Clouds
DECWDLD	Deciduous woodland
CONWDLD	Coniferous woodland
AGRIC	Agricultural fields
GLACIER	Glacier
MIXDECID	Aspen/birch mixed; 60% crown closure
HAY	Hay fields, growing (spectrally bright)
FALLOWAG	Fallow agricultural fields
BOG	Mat-like vegetation on standing water
AQUATIC	Vegetation on standing water, i.e., lily pads
ALPINE	Alpine tundra (dryas, liches, low lying)

of the data to north. Preprocessing functions for the eastern and two western scenes differed and will be described in separate sections.

Preprocessing of the two western scenes included an initial mosaicking of the two scenes, removal of skew, and rotation. All preprocessing of the Susitna scene was completed on the IBM 360/67. The southern half of the northern scene and northern half of the southern scene were mosaicked. Concurrently, the mosaicked scene, referred to here as the Susitna scene, was geometrically corrected to remove distortion inherent in the data and to permit registration to a map base. The data were reformatted to remove skew caused by the earth's rotation beneath the satellite. In addition, the data were rotated to north for ease of use. Parameters for correction of the data, computed by using a program available on the IBM 360/67, were based on the latitude of the center point of the Susitna scene.

DIGITAL ANALYSIS OF SUSITNA SCENE

The supervised approach develops statistical clusters based on the spectral content of selected land cover sites. Success of the supervised approach is based on the quality of training site selection, of ground data collection and analysis methodology. Sites visited during the previous summer met all requirements of spectral homogeneity within land cover categories required for a supervised approach. Spectral variation exists within training sites of the same land cover category and, therefore, may contain several spectral signatures which represent differences in density, slope, soils, or other terrain variables which affect the spectral response of vegetation.

Prior to clustering, coordinates of the training sites delineated on the IDIMS COMTAL display were transferred via the IBM 360/67 to the TENEX computer at BBN. Table 11 gives the number of training sites and number of pixels within each land cover category. A program available at BBN converts the IDIMS training file into a coordinate file compatible with the EDITOR software. A tape containing the MSS data of the mosaicked Susitna scene was also sent to BBN, for retrieval of MSS data during clustering.

MSS data for each training site was retrieved from the data tape and grouped by land cover category. The MSS data of each of these files was displayed in the form of a frequency distribution (histogram) to analyze the data for homogeneity and to determine the number of spectral classes present. Generally, the histogram is analyzed to determine the number of nodes or peaks in the data distribution, the spread or dispersion of the MSS values about the mean, and the range

TABLE 11

	Training Sites	Number of Pixels
DECCON	9	1,417
MIXWOOD	2	106
SHRUB	5	360
BIRCH	12	731
DECID	3	2,640
GRASS	11	505
WATERCL	7	895
MOSSBOG	1	152
TUNDRA	6	4,395
SEDWATER	9	50,816
ICE	3	32,485
CLOUD	1	7,606
CONDEC	3	104
DECWDLD	9	1,149
SPRUCEB	3	112
CONIF	4	360
MIXDECID	4	919
WETLAND	8	190
BSPRUCEB	3	131
ASPEN	1	22
BARREN	1	19
BULRUSH	3	361
GLACIER	2	1,656
ROCK	3	837
ALPINE (TUNDRA)	8	430
MUD	4	2,225

TABLE 11 -- Total number of training sites and pixels for each land cover category.

of values. The histogram shown in Figure 20 has a signature characteristic of the red band for a birch forest; that is, a low variance with one node, and low range of reflectance (dn) values. However, the same MSS data displayed in a near-infrared band (Figure 20) shows two distinct nodes, and a large range of dn values. The infrared bands are much more sensitive to green vegetation and are, therefore, used more often to determine the optimal number of spectral classes present for clustering. In this same way, each file of MSS data by land cover category was histogrammed and examined to determine the optimal numer of clusters.

Clustering was performed on each file of MSS data to develop cluster statistics--means, variances and separability (a measure of distance between clusters). Following clustering, the statistics were examined. Clusters representing the same land cover category with extremely low variances and low separability were pooled, while clusters with high variances and a low number of pixels were reclustered or deleted. Initial clusterings which resulted in clusters with low variances, low separability and a low number of pixels were unsatisfactory. These data were reclustered a second time, partitioning the MSS data into a smaller number of clusters. Each of the MSS files was clustered and reclustered as necessary to develop a preliminary set of statistics representative of all land cover categories found in the training sites.

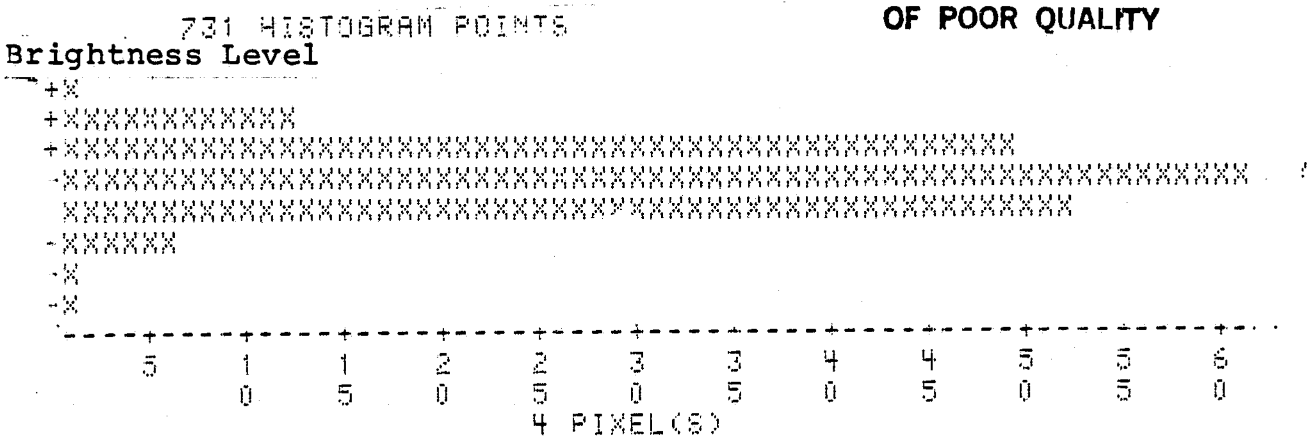
A preliminary statistics file which contained one to several spectral classes was created for each land cover category. For further analysis, each statistics file was graphically displayed as a two dimensional plot representing means and variances. As shown in Figure 21,the axes represent the reflectances values in the red (MSS 5) and near-infrared band (MSS 6).

Means are represented by the cluster number (alpha-numeric) and variances by the surrounding circle. Potential problems, such as clusters with high variances or low separability, were easily identified on the plot.

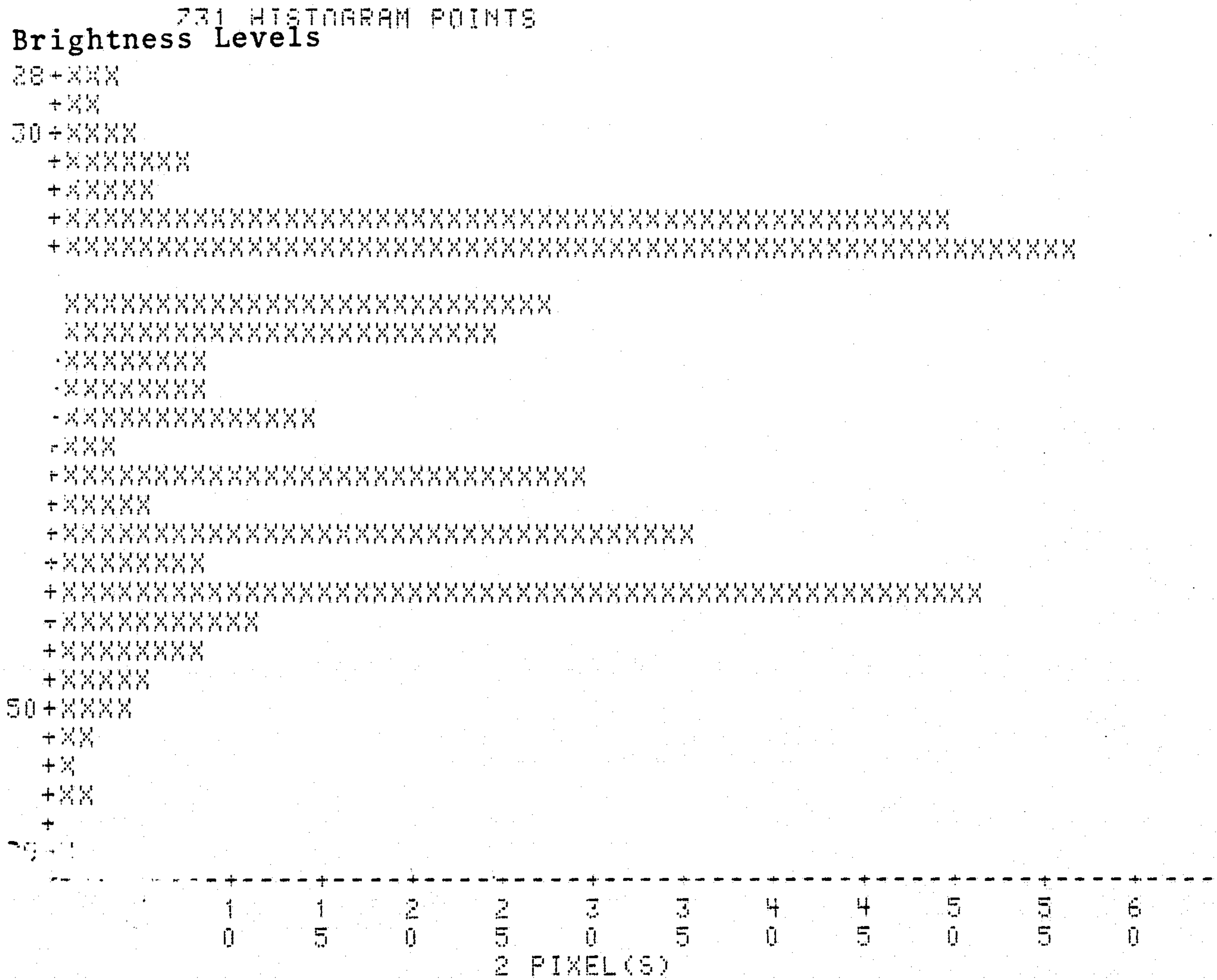
Confusion between clusters of different land cover categories was examined next. Spectral confusion results when two distinct land cover categories encompass the same specral reflectance values in the four bands. Statistics files representing different land cover categories were merged and the separability measure was used to determine possible spectral confusion. Confusion clusters are either pooled, deleted, or reclustered. Many analysis decisions at this point are highly subjective. Each analyst has developed a method for analysis based on experience, training, and intuition. Invariably, this portion of the analysis,

Figure 20
Histogram

ORIGINAL PAGE IS OF POOR QUALITY



Band 5 Visible Red



Band 6 Infrared

i.e., development of the spectral clusters, is the most difficult task and can produce a wide range of results. This process of merging statistics files, editing, and rechecking continues until all statistics files have been merged into a composite statistics file.

To evaluate the integrity of the statistical clusters, the training sites were classified with the composite statistics file representing all land cover categories. Tabulations by land cover category gave an indication of the number of pixels correctly classified within each land cover category. Based on these tabulations, spectral confusion was evident between deciduous forest classes and deciduous/coniferous forest classes; woodland classes and shrub classes; and shrub, grass and tundra classes. The analyst had to determine at this point whether the confusion was due to 1) inadequate training site selection (heterogeneous sites), 2) conflicting land cover classes which were spectrally identical and therefore not statistically separable, or 3) overlapping land cover category descriptions leading to overlapping class names which represent the same cover type. Spectral confusion which existed between shrub, grass, and tundra classes was due to confusion in classificaiton terminology. On the uplands, the training sites labeled tundra actually consisted of shrub and grass occurring above the treeline. Once again the statistics were modified by deleting, pooling, or reclustering and then used to reclassify the training sites. The iterative editing process continued until the analyst felt the statistics were as spectrally distinct as the MSS data would allow. The composite supervised statistics file for the Susitna scene is shown in Figure 21.

Spectral variation within the scene which may have been overlooked was supplemented with statistics generated during unsupervised clustering. The MSS data were retrieved from the data tape by strata (upland and lowland) and clustered in an unsupervised mode. In an unsupervised clustering approach, the MSS data are partitioned into an arbitrary number of spectrally distinct groups or clusters. Due to the large number of pixels in each of the strata, a data reduction program was run. The data reduction program in EDITOR enables clustering of an entire Landsat scene on the ILLIAC IV. The program maintains a count of the number of pixels which have the same reflectance values in the four bands. For the Susitna scene, the MSS data were retrieved by strata and then compressed from 1,727,711 individual pixels to 29,368 different MSS values for the lowland strata. Unsupervised clusters were displayed as two dimensional plots (Figure 22) for examination.

The unsupervised statistical plots were overlaid on the supervised statistical plot for comparison. When an unsupervised cluster occupied spectral space not represented by

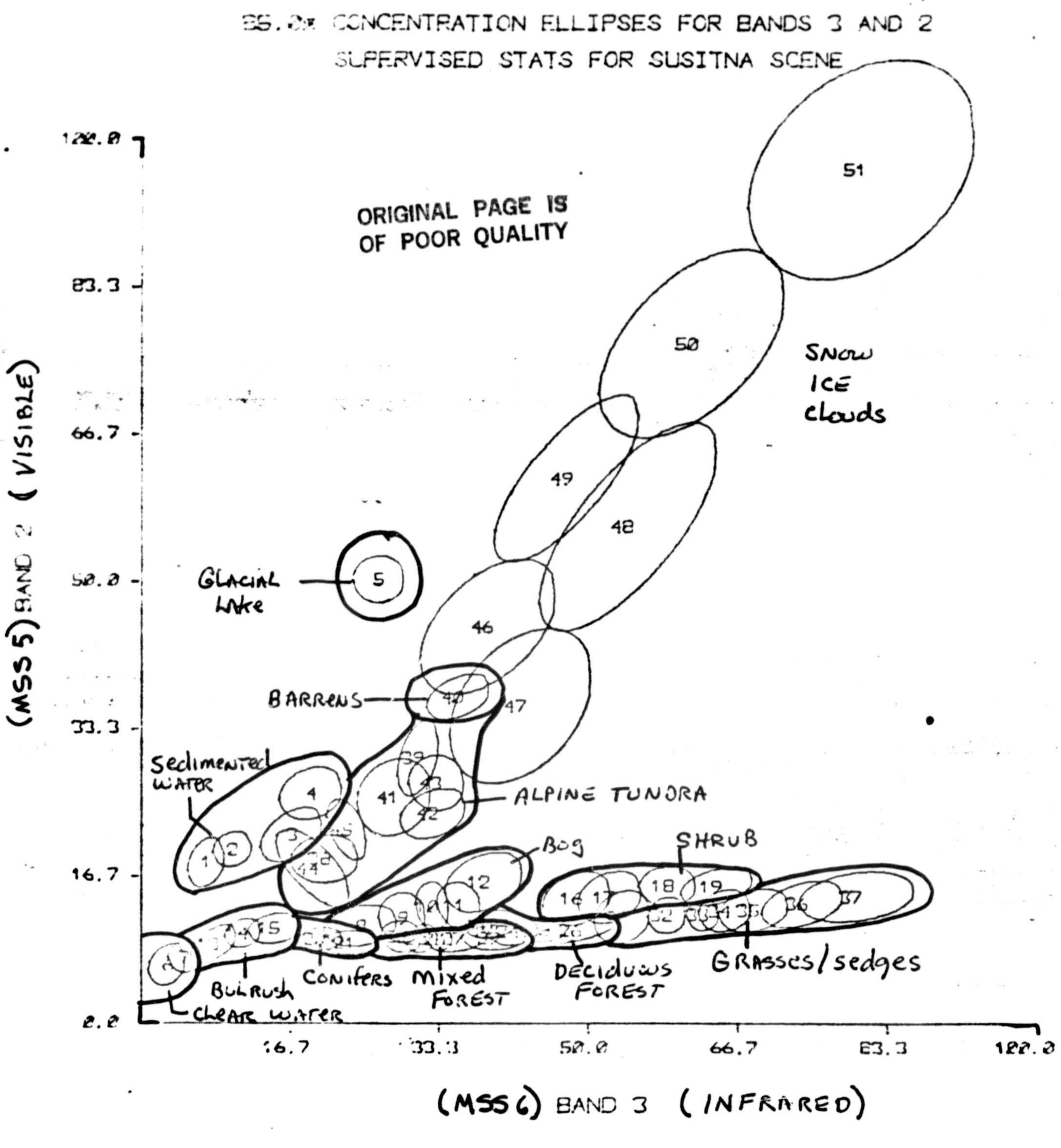
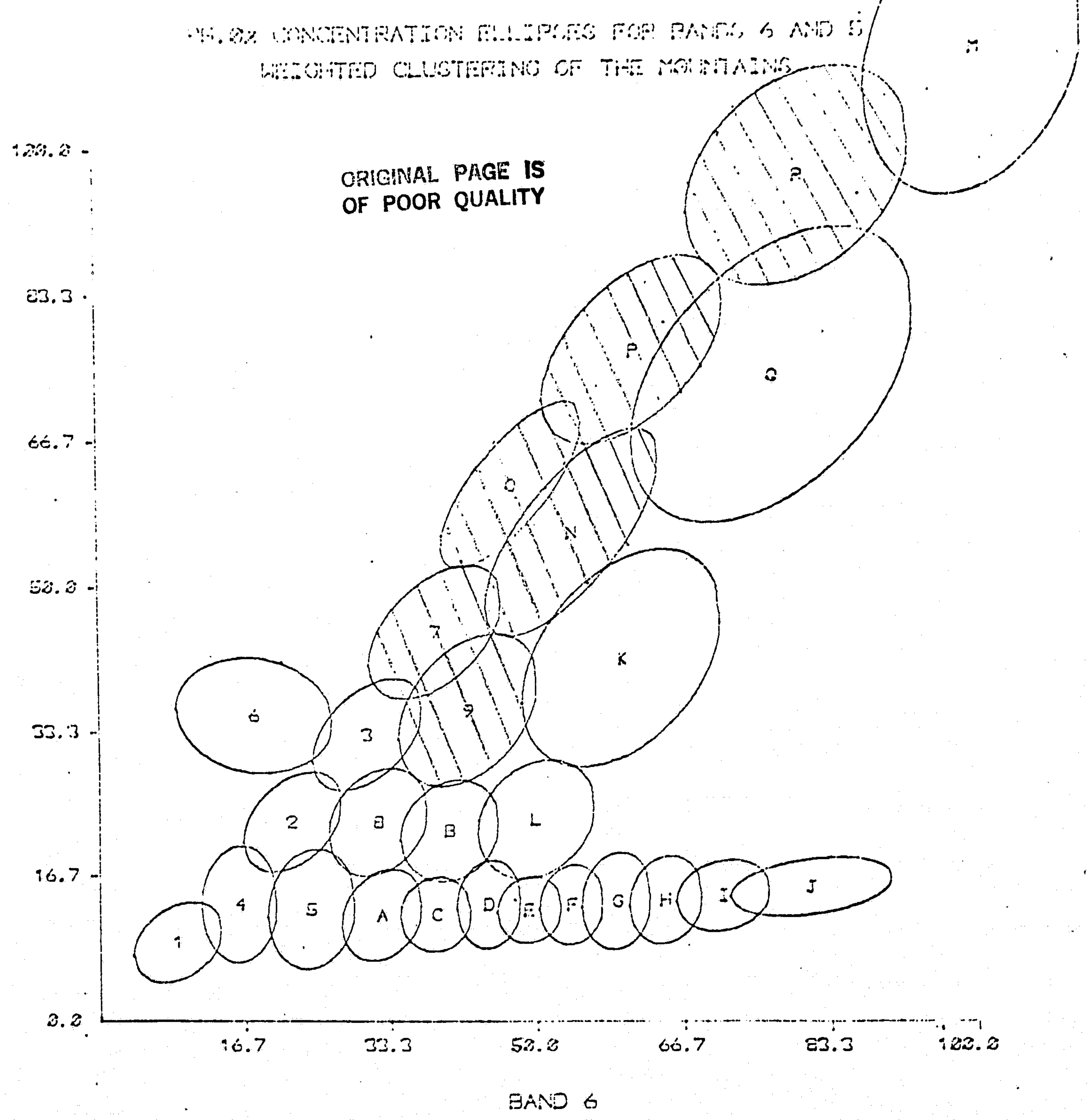


FIGURE 21, COMPOSITE SUPERVISED STATISTICS FILE

FIGURE 22. UNSUPERVISED CLUSTERS FOR UPLAND STRATA



*Cross hatch lines indicate clusters added to the final supervised statistics.

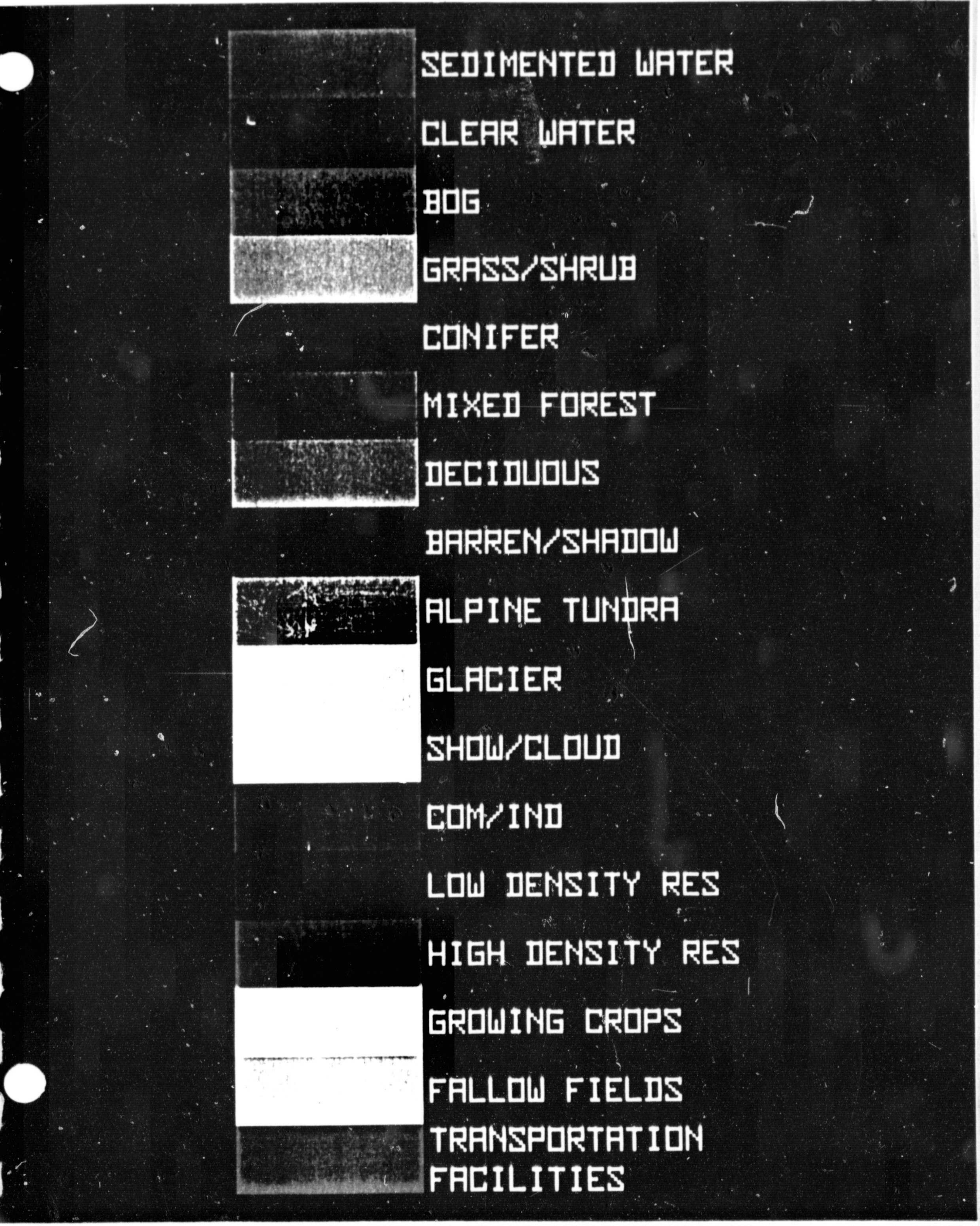
a supervised cluster, the unsupervised cluster was added to the composite supervised statistics file. Snow, ice and cloud clusters from the unsupervised clustering of the upland strata (Figure 22) were added to the final supervised statistics for the Susitna scene. All other land cover categories were represented with supervised clusters.

The data tape and final supervised statistics file with 56 clusters were input to a maximum likelihood classifier, whereby the MSS values of each pixel were examined and it was assigned to the cluster that it most nearly resembled in spectral space. Masked classification of the Susitna scene with 113 classes (56 clusters plus 57 clusters generated on the HP3000 for the Anchorage urbanized area) were completed in 481 seconds on the ILLIAC IV parallel processor.

Digital analysis of the Susitna scene encompassed two major steps: clustering of the MSS data to develop statistics, and classification, a process in which each pixel was assigned to the statistical cluster it most nearly resembled. The combination of supervised and unsupervised clustering maximized computer and analyst time without sacrificing quality. However, to assess the integrity of the spectral classes, CIR photography and the classification were compared in a number of workshops involving State agency personnel. (Figures 23 and 24 show the final classification results for the Susitna scene).

FIGURE 23. SUSITNA SCENE

FIGURE 24.CLASSIFICATION OF LAND COVER IN SUSITNA SCENE



APPENDIX D

INTRISCA PROJECT

DIGITAL ANALYSIS OF THE EASTERN/ANCHORAGE SCENE

Charlotte Carson-Henry

TRAINING, CLUSTERING, AND CLASSIFICATION

The selection of training sites for the eastern (ANCHOR.EAST) scene portion of the South Central Alaska analysis area was conducted concurrently with training site selection for the Susitna scene, during the November 26 - December 27, 1979 user workshops. Tony Burns, of the Municipality of Anchorage, provided training sites for the urbanized areas of Anchorage and Eagle River, along with portions of the Matanuska-Susitna Borough. Ellen Wycoff of Matanuska-Susitna Borough provided additional training sites from that borough although unable to attend the workshops; those sites were delineated by Tony Burns. Robert Loeffler, representing the Planning and Classification section of the Department of Natural Resources (DNR), provided and delineated largely vegetative cover training sites; representations of forest cover types were provided and delineated by Merlin Wibbenmeyer of the Forestry Section of DNR. In all, over two hundred training sites were delineated by these users during the series of three-day workshops at NASA/Ames.

Training site delineation was accomplished on the IDIMS system, using the COMTAL display. Each site was displayed at an expanded level and was outlined on the display using a cursor and trackball; the coordinates for the vertices of the outlined irregular polygons were then stored by the system in a file, under a user-designated training class name. This capability permits the storage of multiple polygons under the same training class name, thereby allowing training on a specific cover type to include spectral differences per cover type and non-contiguous geographic locations of the same cover type. (See Table 12 for a description of the training classes delineated).

The use of a display during training site selection encouraged visual examination of the spectral variations inherent in MSS data; for example, varying spectral responses can occur within a homogeneous stand of timber. Refinement of training site boundaries, relative to this kind of spectral variation, went hand-in-hand with delineation and was made possible by the use of a display. The

TABLE 12

Training Class Descriptions

Training Class Name	Description of Land Cover Types
SANDEXT	Barren: sand/gravel extraction site
WETLAND	Marshy ground; either tidal marshes or upland sedges
MIXWOOD	Coniferous & deciduous mixed woodland
SEDWATER	Sedimented water, shallow or turbid water (spectrally light)
WATERCL	Clear water, deep water (spectrally dark)
AIRPORT	Larger airports
GRASS	Golf courses
SPRUCEB	Black spruce forest (without bog)
TUNDRA	Upland tundra & shrub/grass tundra
SHADOW	Shadows and north-facing slopes
BARREN	Bare rock and soil (non-agricultural) and mudflats
RESIDENT	Urban residential aras
COM	Urban commercial areas
TUNDRA2	Upland tundra with bad data lines
WETLAND2	Wetlands, as above, but with bad data lines
CONIF	Coniferous forest
ASPEN	Aspen forest
SHMOSSB	Shrub/moss bog (includes sedges)
DECCON	Deciduous/coniferous forest, primarily deciduous
SHRUB	Shrubs, e.g. alder and willow
CONDEC	Coniferous/deciduous forest, primarily coniferous
BULLRUSH	Bullrushes in tidal marsh areas
DECWDLD	Deciduous woodland (understory reflectances included)
BIRCH	Birch forest
AGRIC	Agricultural fields, other than hay and fallow
GLACIER	Glaciers
ICE	Snow and ice, other than glaciers
HAY	Green, growing hay fields
FALLOWAG	Fallow agricultural fields
BOG	Mat-like vegetation growing on standing water
AQUATIC	Standing water with vegetation like lily pads
MIXDECID	Mixed deciduous forest: aspen & birch; 60% crown closure
DECID	Deciduous forest; 50% crown closure
BSPRUCEB	Black spruce bog with 10-25% tree coverage of bog
RURALRES	Rural residential areas, i.e. Eagle River Valley
SCHOOL	School sites in Anchorage proper
ROCK	Barren: rocks alone
CONWDLD	Coniferous woodland (understory reflectances included)

visibility of these spectral variations within and between cover type enabled the users to gain an appreciation of spectral reflectances and the complexity of cluster analysis, and added to their understanding of the limitations of Landsat classifications.

In using the IDIMS display for training site selection, anomalies occurring in the data became visible when expansions were performed to faclitate the outlining of polygons. The Landsat imagery corresponding to some of the training sites provided by the users contained these anomalies; in some instances, these training sites were nonetheless delineated on IDIMS but were assigned different training class names to assure that they would be stored separately from unaffected sites. They were subsequently clustered but the cluster statistics were affected by the inclusion of the anomalies in the training sites; those clusters were not used in classification.

Clustering for the ANCHOR.EAST scene was performed on the IDIMS system using the CLUSTER portion of TSSELECT. That software utilizes the IDIMS ISOCLS clustering algorithm. ISOCLS (CLUSTER) is a function which allows user specification of a number of parameters; defaults have been written into the software for use by the algorithm when the analyst makes no specification for a given parameter. Most of the parameters were defaulted when the ANCHOR.EAST training classes were clustered. (Descriptions herein will pertain to the use of the ISOCLS function only as it was employed in this analysis.)

The ISOCLS algorithm begins by placing all pixels in a single cluster, then computes the statistics that describe that cluster. For each band, the mean grey level, the standard deviation in grey level units, and the distance between clusters in terms of grey level units are computed and printed on the line printer. The algorithm then selects the band with the largest standard deviation, and adds or subtracts that standard deviation value to or from the mean for that band, creating the "seed" of a new cluster. Pixels are then assigned to either the original cluster or to the new cluster, depending upon which cluster center the pixel's reflectance value most resembles; resemblance is judged on the basis of the absolute value of the grey level distances between the pixel's values and those of either cluster. Once all pixels in the image have been assigned to one cluster or the other, the statistics (means, standard deviations, and distances) for each cluster are recomputed. This process of creating two clusters from a single cluster is referred to as "splitting"; the algorithm continues splitting clusters until one of two criteria is met: 80% of the clusters have: 1) standard deviations that are less

C-2

than the value entered for the parameter STDMAX, or 2) contain too few pixels to be able to be split and still remain within the lower limit set by the parameter NMIN (minimum number of pixels per cluster). Once one of these criteria is met, ISOCLS begins alternating between splitting and combining: one iteration will split clusters, the next will combine any qualified clusters, the next will again split, and so on. Combining can occur when the computed distance between two clusters (this distance is defined as a weighted measure based on cluster means and standard deviations summed over all the bands) is less than the value specified for the DLMIN parameter. (In this analysis, a value of 3.2 grey levels was used for DLMIN.) Iterations alternate between splitting and combining until one of two conditions is attained: either no clusters qualified for splitting or combining remain, or the number of iterations has reached the maximum limit set by the ISTOP parameter. The attainment of one of these conditions causes the algorithm to enter into the final iteration, which is always a splitting iteration.

For each iteration, cluster statistics are recomputed after the splitting or combining has been performed, and those statistics are printed on the line printer for evaluation by the analyst. In addition, a tabulation of the number of pixels in each cluster, and a map of each training site, are generated on the line printer.

Each training class (BIRCH, ASPEN, SEDWATER, and so on as listed in Table 12) was clustered individually and the resultant cluster statistics were directed to a statistics file bearing the same name as the training class. The cluster statistics (output on the line printer) were then analyzed solely in light of the ISOCLS 80% criteria mentioned previously. Those clusters whose standard deviations failed to meet the 80% criteria were re-clustered, iteratively, until they did indeed meet those criteria. In addition, classes whose cluster statistics were well within the 80% criterion were examined and were re-clustered, in an attempt to bring the standard deviations of the individual clusters closer to the STDMAX value while still meeting the criteria. Each re-clustering was generated so as to create a new and separate statistics file for later ease of manipulation.

Once clustering was completed, the statistics files were edited and merged. The IDIMS function SMART was utilized in the statistics editing and in the creation of a master statistics file, and the statistics files containing all other CLUSTER outputs were deleted. The statistics for several training classes were deleted at this point due to the fact that the sites contained too few pixels to generate valid clusters.

The master statistics file created on the IDIMS system contained more than 100 clusters; this file, however, was not considered to be the final statistics file. Actual evaluation of the clusters was performed on the EDITOR system at BBN by means of cluster plots. In order to generate these plots, the means and variances for each of the 100-plus clusters were manually entered on EDITOR, generating a statistics file. Swain-Fu Distances (a measure of separability between cluster pairs) were generated on that system: some editing of clusters was performed, thereby reducing the number of clusters to 87; and a PLOT file was subsequently created. An ellipse for each cluster was plotted from that file, for MSS Bands 5 and 7. The ellipses reflected both the mean of each cluster and the variance of that cluster, in two-dimensional space. Final statistics editing decisions were based upon evaluation of these elliptical plots. The editing performed on EDITOR was then duplicated on the IDIMS system, using SMART to edit the master statistics file. See Table 13 for a summary of the clustering performed on the ANCHOR.EAST scene.

As a preparation for classification, the ANCHOR.EAST image was submitted to the FIXLINE function on IDIMS for "repair" of lines in which data were missing. The output image from FIXLINE and the master statistics file were then written to tape and submitted to the CDC 7600 maximum likelihood classifier. This classsification program evaluates the spectral reflectance values in all four MSS bands for each pixel, then places that pixel into the class whose statistical characteristics it most resembles.

Following classification, a series of four User Evaluation Workshops were conducted at Ames. The first of these four-day workshops was attended by Lee Wyatt from Matanuska-Susitna Borough and by Tony Burns, the Instate Coordinator, who attended the entire series of workshops. The second of the workshops was attended by Peggy McNees of the Planning and Classification Section of DNR; the third, by Merlin Wibbenmeyer of DNR/Forestry. The fourth workshop was conducted with and for Tony Burns, and focused upon Anchorage and other urban areas, as well as coastal wetlands under the jurisdiction of the Municipality of Anchorage. The objective of each of these workshops was to provide an opportunity for agency personnel to identify the spectral classes resulting from the classification of both 1978 scenes and to evaluate the classifications as a whole, using the IDIMS display as a tool. Since each of these agency personnel had expertise in different types of land cover and differing geographic areas, the series of workshops taken as an entity resulted in evaluation of most of the areas of interest that comprised the study area (such as Point McKenzie, the Eagle River valley, the town of Eagle River,

TABLE 13

ANCHOR.EAST
Clustering Results

Training Class Name	# of Pixels in Training Class	# of Clusters Generated	# of Clusters Used in Clas'n.
SANDEXT	132	3	-
WETLAND	424	4	4
MIXWOOD	272	4	3
SEDWATER	589	3	1
WATERCL	711	4	1
AIRPORT	137	2	1
GRASS	19	1	-
SPRUCEB	256	1	1
TUNDRA	857	10	7
SHADOW	212	3	3
BARREN	255	5	4
RESIDENT	248	5	4
COM	185	4	1
TUNDRA2 **	126	3	-
WETLAND2 **	258	2	-
CONIF	694	3	2
ASPEN	61	1	-
SHMOSSB	1245	5	5
DECCON	621	1	1
SHRUB	204	4	2
CONDEC	40	1	-
BULLRUSH	553	3	1
DECWDLD	457	2	1
BIRCH	329	4	1
AGRIC	45	1	-
GLACIER	3203	20	19
ICE	2240	7	5
HAY	184	4	3
FALLOWAG	93	2	1
BOG	159	3	2
AQUATIC	146	2	1
MIXDECID	578	1	1
DECID	905	5	5
BSPRUCEB	327	4	4
RURALRES	497	5	4
SCHOOL	20	1	-
ROCK	45	1	-
CONWDLD	22	1	-

** Training classes within which missing data lines occurred

Big Lake, and the Palmer-Wasilla area). Vegetation types -- in particular, forest and wetland cover types -- and urban land cover types were carefully examined and evaluated in these and other areas using U-2 photography and field data as ground information. Available specialized land cover/land use maps were also consulted in evaluating the spectral classes, particularly in Anchorage and in the coastal wetland areas on the north side of Turnagain Arm. Table 14 reflects the preliminary identifications made.

POST-PROCESSING

During the evaluation workshops, extensive records were made regarding the type and location of blatantly incorrect classes, as preparation for stratification to refine the classification.

Fairly extensive stratifications were requested by the users in the urban areas of Palmer, Wasilla, and Eagle River; along the lowlands on the north side of Turnagain Arm, such as Alyeska, Portage, and Girdwood; and in the upland areas, in which barrens had been incorrectly classified as water. Conflicts between natural vegetation types and agricultural fields and between urban and barren cover types occurred, as expected, and conflicts between minor transportation corridors and shrub/grass categories emerged as well.

Stratifications for the purpose of changing classes within a specific area were accomplished with the function ZIP on the IDIMS system. ZIP allows the analyst, using a cursor and trackball, to outline on the display the area within which the class changes are to be made. The program then records the vertices of the polygon in a training file. (ZIP utilizes the software described in the section of this paper regarding training site selection.) Although a temporary hardware failure severely hampered the use of the ZIP function (thereby extending the time required to complete stratification), ZIP does nonetheless provide a preferable alternative to the standard method of stratification -- which requires the digitizing of polygons and the translation of the polygon information into strata that are subsequently merged with the Landsat classified data. The ZIP function does contain a trap, however: since the output from each ZIP becomes the input to the next ZIP, any error that is made tends to be perpetuated as subsequent ZIPs are performed.

Following completion of the iterative stratifications performed on the ANCHOR.EAST classified image, the process of identification of individual classes was repeated pertaining to the ZIPped image. U-2 photography and field data were again used in the identification of classes and in the

TABLE 14

Class Identification

Preliminary identification, following preliminary grouping of Tundra, Glacier, and Ice categories:

Class Label	Class Number(s)
Deciduous	1-5
Wetland	6-8
Mixed woodland/Mixed forest	9-11
Sedimented water	12
Clear water	13
Black spruce bog	14-17
Airport/Barren	18
Rural residential/Sedges/Grasses	19-22
Black spruce	23
Tundra	24
Shadow	25-27
Barren	28-31
Residential/Sedges/Grasses	32-35
Commercial/Barren	36
Coniferous	37-38
Shrub/Moss bog	39-43
Deciduous/Coniferous	44
Shrub	45-46
Bullrush	47
Deciduous woodland	48
Birch	49
Hay	50-52
Fallow agriculture/Barren	53
Bog/Clear water	54-55
Aquatic	56
Mixed deciduous	57
**	58
**	59
**	60
**	61
**	62
**	63
Glacier	64
Ice	65

** Class numbers 58-63 left open for classes resulting from stratifications.

correlation of these spectral classes with ground cover types. The IDIMS display was again used; concurrently, groupings of spectral classes into information categories were assigned, preparatory to the running of a program to actually aggregate the classes.

Post-processing continued with the running of the program ROTATE on the IBM 360/67. This program deskewed the classified, stratified image and rotated it so that a north/south line drawn through the image was vertical. The extent of rotation to be applied to the image was calculated on the IBM 360 using a program called SKEW; the parameter used to specify the extent of rotation was the same as that used in the rotation of the Susitna imagery for the INTRISCA classification of 1978 data.

Following rotation, the ANCHOR.EAST image was submitted to the GROUP program on the IBM 360 to aggregate the classes into the information categories mentioned above. In addition to the aggregation of spectral classes into information categories, GROUP was used to change class numbers (for aggregated groups); the result was that information categories were identified by the same class numbers in both the ANCHOR.EAST and Susitna scenes. This scheme was adopted to later facilitate a photomosaic output product. The output from GROUP was then smoothed, using the RECLAS program on the CDC 7600. RECLAS utilizes a nine-pixel neighborhood whose weighting factors are specified by the analyst; in this instance, the center pixel was assigned a factor of 4, the pixels adjacent to the center were assigned a factor of 2, and pixels in a position diagonal to the center pixel were assigned a factor of 1. The program moves this nine-pixel neighborhood through the image, reassigning categories according to the specified neighborhood weighting factors. In addition, the analyst is able to specify weightings for individual categories; these category weightings will override the neighborhood weighting factors to cause specified categories to assume lesser importance as they contribute to a neighborhood. This program mimics a nine-acre minimum mapping unit, and tends to merge isolated incidental pixels with the categories by which they are surrounded. The effect of RECLAS on the ANCHOR.EAST imagery was to reduce the number of pixels that had been spuriously classified due to the banding in the raw data, as well as to eliminate the speckled appearance caused by isolated occurrences of classes.

The effects of these post-processing steps were evaluated on IDIMS, again using the COMTAL display as a tool. It is important to note at this point that a major objective in the post-processing steps was the facilitation of a photomosaic of the ANCHOR.EAST scene with the Susitna scene. In

order for the photo-mosaic to be successful, it was essential that the two scenes be processed similarly and that the classifications in the overlapping area between the two scenes be as consistent as possible. It was therefore determined, when examining the smoothed form of the ANCHOR.EAST classification, that the grouping and smoothing that had been performed had been unsatisfactory. Using the IDIMS display capability, several additional aggregation schemes were evaluated and the most promising was then used in re-running GROUP. The RECLAS program was subsequently re-run on the new GROUP output, utilizing the capability for weighting individual categories (which had not been used the first time RECLAS was run)(Table 15). Classes comprised of an insignificant number of pixels, and classes that had resulted from anomalies and which bore no relation to a given land cover type, were weighted in a fashion that essentially caused them to be reclassified according to the neighborhood weighting factors mentioned previously. Classes 15, 46, 55, 56 and 68 were assigned an individual weight of 0.5, while class 25 was assigned an individual weight of 0.1. The use of these weights caused occurrences of these classes to be either reduced or eliminated, with the weighted classes having been reassigned to categories that were more accurate when verified with ground data and photography. The output from the second grouping and smoothing was also much more satisfactory in terms of compatibility with the classification of the Susitna scene, in light of the planned photo-mosaic.

OUTPUT PRODUCTS

Due to the complexity of potential user requirements for output products--regarding geographic areas of coverage, class aggregations, and map scales of both photo products and computer-generated maps--a determination was made that a standard set of output products would be generated and would serve as samples, to the users, of the types of products available. This set of products was designed to focus upon geographic areas of concern to the largest number of users, with products to be generated at scales corresponding to existing base maps. The set included:

Point McKenzie subsection, color Dicomed enlarged to scale of 1:63,360

Susitna River to Big Lake subsection, color Dicomed enlarged to scale of 1:250,000

Anchorage Peninsula subsection, color Dicomed enlarged to scale of 1:25,000

Palmer agricultural area subsection, color Dicomed enlargement at scale of 1:63,360

TABLE 15

ANCHOR.EAST
Final Grouping
Class Identification

After completion of stratification, prior to smoothing:

Class Label	Grouped Class Number	Class Numbers Combined to Comprise Grouped Classes
Deciduous	9	1-3,48-49
Sedges/grasses*	27	19-20,34-60
Mixed forest	8	4,9-10,26-27,44,57
Sedimented water	1	12
Clear water	2	13,47,54-55
Black spruce bog**	4	14
Residential, low density	19	61
Tundra, alpine***	11	6-8
Shadow	15	68
Barren #	10	18,28-31,36,53
Residential, high density	18	58
Commercial/industrial/trans.	16	59
Coniferous	7	5,11,15,17,22-23,25,32-33, 35,37-38,46
Shrub/moss bog**	3	16,21,40-43,56
Shrub*	6	39,45
Hay	23	62
Fallow agriculture	24	63
Glacier	12	64
Ice, snow	13	65
Mud #	25	67
Grass*	5	50-52
Shrub/grass tundra***	26	24,66

* To be grouped together in output products
** To be grouped together in output products
*** To be grouped together in output products
\# To be grouped together in output products

Eagle River subsection, line printer map at scale of 1:24,000

Anchorage Peninsula subsection, line printer map at scale of 1:24,000

Susitna River to Big Lake subsection, pixel count on IBM 360 for acreage tabulations

Susitna River to Big Lake subsection, pixel count on IDIMS for percentage of coverage tabulations

In addition to the above products, the set included a Dicomed print of the two classified scenes photo-mosaicked together. Color bars will be manually attached to each photo product. A major feature of this set of output products is that the set also includes a negative of each of the photo products, enabling users to generate photographic enlargements of areas or subsections not included in the standard set--according to their individual needs and at the time their additional requirements emerge.

Plotter maps, to be generated on the SEL, had been intended for inclusion in the output products set as well as the items mentioned above. The plotter maps of the Palmer agricultural area and of the Susitna River to Big Lake subsection were, however, not generated due to hardware limitations: the smallest print size of SEL plotter symbols is too large to produce a map at a scale of 1:63,360, as had been planned. Although multiple attempts were made to generate plotter maps at this scale, the horizontal and vertical shifts required to make the plotter map overlay a base map varied from ¼" to several inches over a distance of 8 linear inches. The line printer maps generated at 1:24,000 scale will, nonetheless, suffice to illustrate the capability of producing maps of the classified data.

APPENDIX E

INTRISCA PROJECT

STRATIFICATION OF

SOUTHCENTRAL WATER LEVEL B STUDY

L. Morrissey

State, federal, and local agencies in the Cook Inlet Region are working in cooperation with NASA to implement state-of-the-art remote sensing techniques to develop a regional resource data base. Integrated Resource Inventory for Southcentral Alaska (INTRISCA) is a multifaceted demonstration project undertaken to meet regional resource management objectives and informational needs. The main objective of the project will be to demonstrate the feasibility of producing a land cover inventory with Landsat digital data.

The Southcentral Alaska Water (Level B) Study utilized Landsat digital data to provide land use/land cover information for future management of land and water resources. The land cover classification for the Water Resource Study was completed by Dr. P. Krebs and P. Spencer of the University of Alaska. Products from the classification will be evaluated by NASA and participating agencies to determine their usefulness in meeting state agency needs. As part of the INTRISCA project, NASA will correct major classification errors through the use of a number of stratification techniques. The stratification of the Water Resources Study (Level B) classification are documented in this paper. Following the evaluation, NASA will begin a new classification to produce a more recent data set which is more specifically related to individual agency needs.*

One source of classification errors in Landsat analysis work is the result of spectral confusion between two distinct land cover categories. Each spectral class is supposed to represent a specific land cover category. However, problems arise when two distinct land cover categories have similar spectral reflectance values. Stratification techniques have been developed to resolve this type of classification error. Where problem areas exist, boundaries are delineated to encompass the misclassified spectral classes. Conflicting spectral classes within specified polygons are reassigned to the correct land cover category.

Evaluation of the Level B work was begun in the spring of 1979 by NASA. Utilizing the IDIMS COMTAL display, spectral class assignments were verified based on available U-2

* See Appendices C and D.

photography. Critical examination indicated a number of problems which could be resolved with stratification. Most notably, a number of spectral classes encompassed urban, tundra, grassland, and barren categories. Major classification errors involved confusion between grasslands and alpine tundra, urban and barrens, and barren and water on the northfacing mountain slopes. Spectral confusion between wetlands and forested lands could not be resolved with stratification because digitization of strata boundaries would have been much too complex and time-intensive.

Preliminary stratification strategies involved reassignment and reidentification of spectral classes within physiographic provinces. Upland areas were delineated by digitizing along the 200-meter contour of 1:250,000 topographic maps using EDITOR (ERTS Data Interpreter and TENEX Operations Recorder) software and an ALTEK tablet digitizer. Calibration files were generated to correlate latitude and longitude to row and column coordinates of the Landsat data to be able to precisely overlay the strata or boundary information onto the data. In addition, the Anchorage urbanized area was stratified. Spectral classes within the urban and upland strata were assigned new spectral class numbers using the FLDMASK program available on the IBM 360 at Ames.

Participants from several state agencies attended a week-long digital workshop at Ames to evaluate the stratified Level B classification. Preliminary evaluation by workshop attendees indicated that a number of classification errors were still evident. The Anchorage urbanized area boundary delineated for stratification was unsatisfactory. The boundary was redigitized using a 1:25,000 topographic map for more accurate definition. Additionally, suggestions for other strata included the Eagle River urban area and Palmer agricultural region.

Preliminary output products were generated and distributed to agency personnel. The products included Dicomed enlargements of the classification aggregated by color into major land cover categories. Line printer maps (1:24,000) and Versatec plotter maps (1:63,360) were also made available. An illustration poster was designed describing stratification of Level B classification. (Figure 8).

The Palmer agricultural region and Eagle River urbanized area were stratified to eliminate confusion between agricultural fields and grasslands, and barrens and urban categories. Each spectral class within the above strata was renamed and reidentified using U-2 photography. Spectral class stratification and reassignments for all strata are shown in Table 16.

TABLE 16

STRATIFICATION REFINEMENTS

Original Spectral Class	Renamed Class
UPLAND STRATUM	
4, 5, 7, 11, 12, 13, 20, 25, 26, 28, 30, 31, 32, 37	44 Barrens
33	45 Mixed Rangeland
8, 15, 17, 24, 29	46 Alpine Tundra
EAGLE RIVER STRATUM	
5	44 Barrens
15, 32	48 Residential--low-density
7, 13, 17, 20, 31	49 Commercial/Industrial
FORT RICHARDSON STRATUM	
5, 7, 13, 22, 29, 31	50 Commercial/Industrial
17	51 Residential--high-density
21	52 Residential--low-density
ANCHORAGE URBAN STRATUM	
5, 7, 13, 22, 29, 31, 32	53 Commercial/Industrial
20	54 Residential--high-density
17	55 Residential--low-density
PALMER AGRICULTURAL STRATUM	
15, 17, 20, 21, 24, 29, 33	47 Agriculture

Refinements to the Level B classification (originally with 43 spectral classes) separated an additional six land cover categories: grasslands, alpine tundra, commercial/industrial, low- and high-density residential, and agricultural fields (Table 17). Color-coded Dicomeds of the Level B classification before and after stratification have been generated for the entire Landsat scene, Anchorage urban area, Eagle River Valley, and Palmer agricultural region. Numerous Dunn 35mm slides have been generated to document the stratification process.

Stratification of the Level B classification provided new insight into the potential problems which may be encountered with the upcoming 1978 Landsat analysis. Strategies for classification of the 1978 Landsat data involve clustering and classification within major ecological and urban strata to minimize spectral confusion. The MSS data will be stratified prior to clustering and classification to reduce post-processing stratification requirements.

TABLE 17

FINAL LEVEL B CLASSIFICATION LEGEND

Land Cover Category	Spectral Classes
Coniferous Forest	9
Deciduous Forest	2, 6, 10
Deciduous Forest/Wetlands	23
Mixed Forest/Wetlands	3
Mixed Rangelands	1, 14, 19, 21, 27, 45
Grasslands	17, 24, 29, 23
Wetlands (includes Black Spruce Bog)	16, 26
Alpine Tundra	46
Barrens	5, 7, 12, 13, 15, 20, 22, 25, 31, 32, 35, 37, 40, 44
Deep Water	34
Freshwater Lakes	4, 18, 28, 30, 36
Shallow/Turbid Water	8, 11
Commercial/Industrial	49, 50, 53
Residential--high-density	51, 54
Residential--low-density	48, 52, 55
Snow/Ice	38, 39, 41, 42, 43
Agriculture	47

NOTE: Spectral classes (44-55) created through stratification are underlined

APPENDIX F

INTRISCA PROJECT

INTERPRETING COLOR ENHANCED LANDSAT SINGLE CHANNEL IMAGES OF WATER BODIES

Lindsey V. Maness, Jr.

Varying degrees of knowledge about water clarity, depth, circulation patterns, suspended sediment load, algal distribution, etc., can be derived from either raw or enhanced Landsat imagery. This document describes general principles for the interpretation of one specific type of digitally enhanced Landsat image, that for which a different color has been assigned each Dn (or reflectance value) per MSS band.

At the present time, the NASA/Ames Research Center remote sensing facility has the capability to assign thirty-nine different colors on photo products generated by the Dicomed film recorder. In the INTRISCA Project, the general order of grouping of colors used for water studies is violets, blues, greens, yellows, oranges, reds, browns, and greys. On the images so generated, a black is equivalent to a zero, a white to a one, a violet a two, ... and a dark grey a thirty-eight.

On the right hand side of each image is a color bar with the reflectance values corresponding to each color indicated. It is a simple matter to cross reference a color observed in the water with its Dn (reflectance) on the color bar. In this way, the more time-consuming and less accurate microdensitometry method can be avoided entirely. Using enhanced Landsat imagery, water circulation models which include spatial information about suspended sediment transport, shallowness, turbulent flow patterns, etc. can be quickly constructed and evaluated by planners.

The annotated legend at the bottom of each image includes information about the MSS band, the geographic location, Landsat Scene ID, project title, etc.. The most important of these for analytical purposes is the MSS band, whether 4, 5, 6, or 7. MSS4 measures reflected green light, 5 reflected red, and 6 and 7 two parts of the near-infrared. In terms of water depth penetration, MSS4 penetrates deepest, followed by MSS5, 6, and 7. While depth penetration is negligible (a few centimeters) on MSS7, MSS4 penetrates much deeper, as much as fifty meters under exceptional circumstances with high gain settings and high sun angle (e.g., the Bahamas) but is probably less than two meters in highly sedimented Alaskan waters, such as Upper Cook Inlet.

The following is a generalized description of the meaning of the reflectance of water as measured by each of the four Landsat MSS bands. To be valid, interpretations of the enhanced imagery should be made in conjunction with other sources of data such as topographic/bathymetric maps, tidal stages, etc..

The general principle for MSS4 is depth delineation. If the bottom is visible, the shallower the water, the brighter the reflected light, all other variables held constant. For example, this principle does not hold true in areas with variable suspended sediment loads, algal concentrations, or colors of river bottom sediments. In deep water, the green light usually scatters from suspended sediment and plankton without (noticeably) penetrating to the bottom, so that beyond a certain depth MSS4 loses its utility as a depth mapping tool. Studies have found good inverse correlations between MSS4 reflectance and secchi disc depth in clear waters. For image 30175-20345 MSS4, there are several washed-out bluish-colored lakes (e.g., Big Lake) in the northwest portion of the photograph with reflectances of 10 and 11; this indicates relatively deep, clear water with little sediment. In the northeastern portion is an elongated red lake (Eklutna Lake) with reflectances in the high 20s; this indicates either a very high suspended sediment load (glacial flour?) or shallowness, or both.

The general principle for MSS5 is a hybrid of depth penetration and sensitivity to suspended sediment. MSS5 reflectance correlates directly and well with suspended sediment turbidity. Note that in the areas north and south of Fire Island several dark green areas (Dn=17, 18) are surrounded by lighter greens and yellows (Dn=19, 20) showing two regimens of suspended sediment transport; turbulent flow north of Fire Island and laminar flow to the south of Fire Island. These flow patterns are not evident on MSS4. Their presence on MSS5 implies that this is more than simply a surface phenomenon (as on MSS7). Subaqueous near-shore sediment transport near marshes and mud flats is also delineated with different colors (Dn's) on MSS5.

The general principle for MSS6 is near-surface (perhaps one-half meter or less) depth penetration with extremely good sensitivity to chlorophyll and good sensitivity to suspended sediment, if present in sufficient quantity (as it is in these images). Near-surface sediment transport patterns are easily discerned with the interpretation principle being that the higher the reflectance, the larger the near-surface suspended sediment load.

The general principle for MSS7 is the surface (a few centimeters maximum depth penetration) measurement of

chlorophyll (extremely good) and suspended sediment (good). If there is no chlorophyll and no suspended sediment, the Dn of MSS7 over water is at or near zero since MSS7 absorbs near infrared radiation very effectively. With increases in chlorophyll and/or suspended sediment, the reflectance increases.

Users who are familiar with the sediment loads, depths, and other variables in the rivers and lakes near Anchorage should find these images a useful ancillary source of data for modelling and planning purposes.

Figure 25 is an example of a color enhanced single channel image of scene 21288-20253, MSS 5.

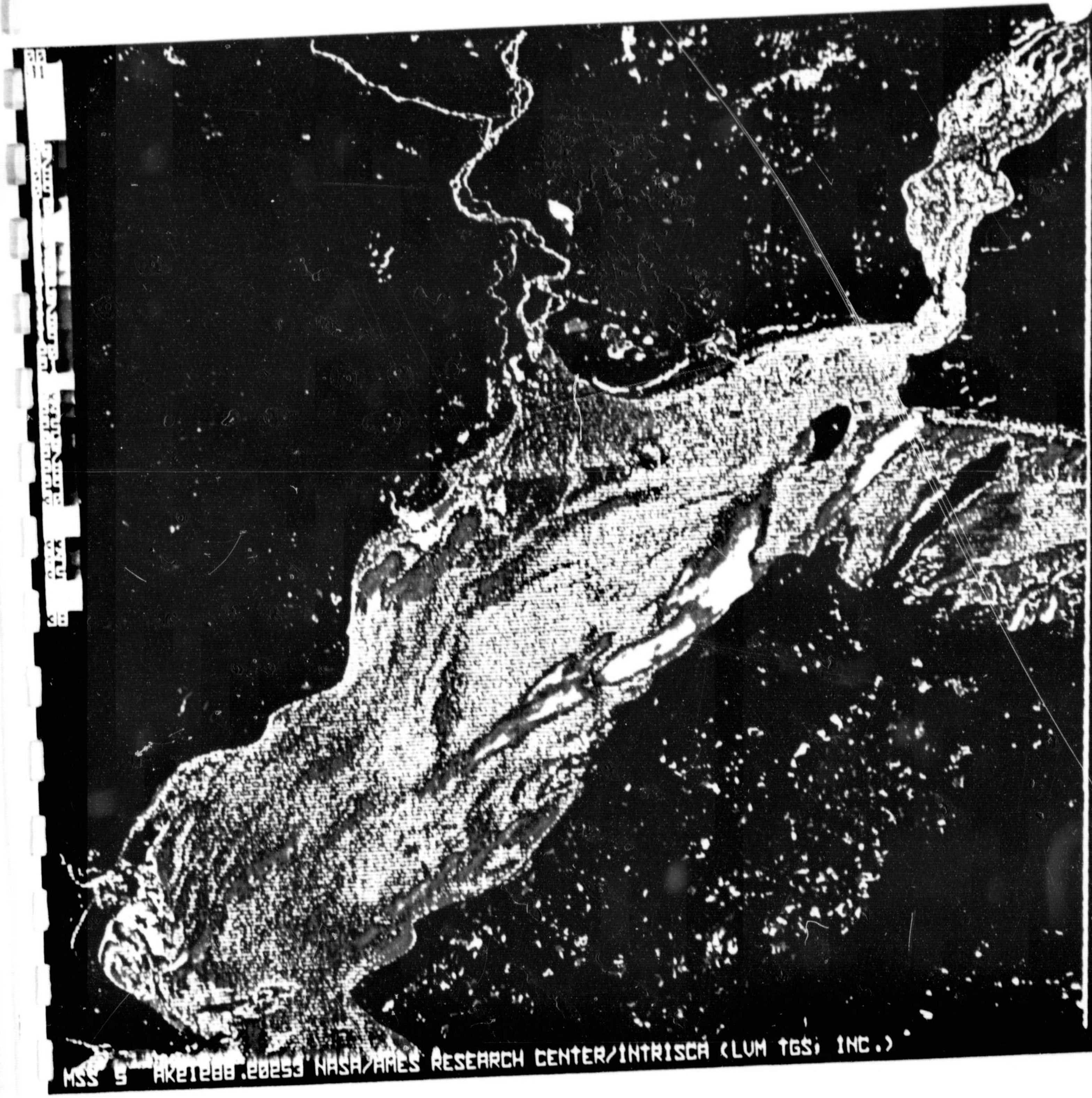


FIGURE 25.COOK INLET COLOR ENHANCED SINGLE CHANNEL
IMAGE BAND 5

ORIGINAL PAGE
COLOR PHOTOGRAPH

APPENDIX G

INTRISCA PROJECT

WATER CIRCULATION IMAGES OF UPPER COOK INLET, ALASKA: LANDSAT DIGITAL ENHANCEMENT TECHNIQUES ON IDIMS

Lindsey V. Maness, Jr.

This document describes the steps necessary to create on IDIMS the type of images delivered to Alaska/INTRISCA to aid in the analysis of water circulation in the Upper Cook Inlet region.

PLANNING SESSION PRECEDING TECHNIQUE APPLICATION

Initially, instructions were given to treat each separate image as if it were a classified image, assigning colors to enhance water circulation. Upon trying this approach, it became immediately apparent that the similarity in spectral characteristics between land and water, especially on MSS 4 and 5, and to a certain extent on MSS 6, would result in images that would be very difficult or even impossible to analyze. The next question asked was: "Is there any way to mask out the land so that only the water remains unchanged on each band?" Several strategies were discussed but eventually the decision was made to follow the strategy of creating an image with the characteristic that all water pixels have a value of unity (one) and all land pixels have a value of zero; to multiply this image with the raw Landsat image to create an image with unchanged numerical values for water and all zero values for land (e.g. any number times zero = zero; any number times one = that number). Then each MSS band was to be treated as a separate classified image, colors assigned to ('class') numbers, and photo products generated.

OPERATIONAL STEPS

Log onto IDIMS and bring the raw image on line for display purposes. All you really need to work with at this time is MSS 7. The water pixels and land pixels should be easily differentiable visually on MSS 7. Use the display MAP function to determine where to make the numerical break point between land and water on the mask to be generated. Do this by typing in at the terminal the following commands until the image you see has water all in white and land all in black:

```
MAP 0 1 10 11 255 TO 0 255 255 0 0
MAP 0 1 11 12 255 TO 0 255 255 0 0
MAP 0 1 12 13 255 TO 0 255 255 0 0
MAP 0 1 13 14 255 TO 0 255 255 0 0
.
.
.
```

and so forth .

Next, mark down for future reference the break point number between land and water. In the case of scene AK30175-20345, the break point was 18; this is the example used in this document.

In other words, when the command:

```
MAP 0 1 18 19 255 TO 0 255 255 0 0
```

was typed in, all the water on the screen was white and all the land was black, which told us that only water had Dn's (digital numbers) values between 1 and 18, inclusive. In this case, the zero value pixels were edge-of-frame (non-image) areas and Dn's greater than 18 were land.

Doing the actual masking interactively is a waste of valuable operator and display device (CRT) time. I recommend very, very strongly that the job be done overnight in the batch mode when no other users will be inconvenienced; this will give you, the analyst-user, time to spend on another task. To set up the batch job to (1) create the mask and (2) to mask out the land, do the following steps in the sequence presented.

CREATING THE MASKED IMAGE

(1) :HELLO username,userid.IDIMS
(2) :EDITOR
(3) Add 1
(4) !JOB jobname,userid.IDIMS,groupname
(5) :RUN IDIMS.PUB;LIB=P

```
(6)  raw.image.name>LOAD
(7)  raw.image.name[4]>MAP(FROM=0 1 18 19 255 TO=0 1 1 0 +
     0)>mask
(8)  raw.image.name[1] mask>MULTIPLY>masked.MSS4.REAL
(9)  masked.MSS4.REAL>CONVERT(OUTYPE=BYTE SPECTYPE=BB)>+
     masked.MSS4.BYTE
(10) masked.MSS4.REAL>DELETE

(11) raw.image.name[2] mask>MULTIPLY>masked.MSS5.REAL

(12) masked.MSS5.REAL>CONVERT(OUTYPE=BYTE SPECTYPE=BB)>+
     masked.MSS5.BYTE

(13) masked.MSS5.REAL>DELETE

(14) raw.image.name[3] mask>masked.MSS6.REAL

(15) masked.MSS6.REAL>CONVERT(OUTYPE=BYTE SPECTYPE=BB)>+
     masked.MSS6.BYTE

(16) masked.MSS6.REAL>DELETE

(17) raw.image.name[4] mask>MULTIPLY>masked.MSS7.REAL

(18) masked.MSS7.REAL>CONVERT(OUTYPE=BYTE SPECTYPE=BB)>+
     masked.MSS7.BYTE

(19) masked.MSS7.REAL>DELETE

(20) masked.MSS4.BYTE masked.MSS5.BYTE masked.MSS6.BYTE +
     masked.MSS7.BYTE>UNITE(SPECTYPE=BB)>AK30175.20345.MASKED

(21) >LISTCAT(FORM=COMPLETE)

(22) raw.image.name mask masked.MSS4.BYTE masked.MSS5.BYTE +
     masked.MSS6.BYTE masked.MSS7.BYTE AK30175.20345.masked>STORE

(23) >END

(24) !EOJ
```

(25) put two slashes in here to get out of ADD mode in Text Editor

```
(26) GATHER ALL;KEEP jobname,UNN;LISTALL,OFFLINE;END

(27) :BYE
```

(28) You have just completed creating a STREAMJOB file. Go to the System Operator. Tell him you have a STREAMJOB you wish to be run in the evening; tell him the file-name (same as jobname on step 26 above), userid, and

that the STREAM (batch) job will create new images for him to store prior to his SYSDUMP the next morning. He can determine the STORE tape(s) to mount by typing =RECALL on the System HP console. Be prepared to show him a copy of what you just did. Also, the Systems Manager or Operator should be able to explain to you the rudiments of the EDITOR system you have to use to create the STREAMJOB file, such as modifying or deleting lines, etc.. (Note: The = in the =RECALL four lines above refers to the CONTROL A symbol [shows up as = on most HP terminals].)

EXPLANATION OF STEPS USED IN CREATING THE MASKED IMAGE

(1) Log on procedure

(2) Getting into the IDIMS Text Editor mode to create a STREAM (batch) job file.

(3) To start a new file, use the command ADD 1.

(4) Line #1 of the STREAMJOB. I am using the convention here that capital letters denote mandatory words; lower-case letters denote assigned words that will vary from user to user. While this is a convention followed throughout this document, I have labeled in later steps the MSS band and datatype in capital letters on image names to emphasize the importance of following some naming convention that is understandable to you and to anybody else who might be working with you.

(5) Commands to enter the IDIMS package of computer software, same as that used for interactive work.

(6) This is one of the many ways to bring an image on-line on IDIMS. Using the command LOAD informs the computer the image is not to be displayed on the TV screen as soon as it has been loaded.

(7) Creating the mask from the break-point parameters derived during the earlier interactive session using the display device. Note: Please look under OPERATIONAL STEPS section, paragraph 2, this paper, for break-point numbers. (Note: One of the reviewers (R. Wrigley) of this document stated that a better way of doing the same thing without creating intermediate REAL form images would be to create a mask with land values equal to zero and water values equal to 255, and then to use the mask and raw images with the IDIMS function AND to create directly each single-banded masked image in BYTE form. I haven't tried this technique, but if

it works as it should, about 80% less computer (CPU) time will be needed to do the work described in this document.

(8) Multiplying the mask with the raw data image creates a masked image (in this case, MSS4) that is in REALform. REALform data are very system unfriendly, so whenever it is possible, you want to convert them to a more friendly data type. By system unfriendly, I mean that REALform data take up tremendous amounts of disc space and burn up extraordinary amounts of computer time; but on IDIMS, any time the MULTIPLY function is run, the output image will be REALform. Also, please review the note in step 7 regarding a way to avoid creation of REALform images and the comments in steps 4 regarding image naming conventions.

(10) Delete the unneeded previously-converted REALform image.

(11) See comment in step 8.

(12) See comment in step 9.

(13) See comment in step 10.

(14) See comment in step 8.

(15) See comment in step 9.

(16) See comment in step 10.

(17) See comment in step 8.

(18) See comment in step 9.

(19) See comment in step 10.

(20) Unite the created masked images into a single four-band masked image. It is advisable to unite them in the sequence MSS 4, 5, 6, and 7 to minimize later confusion. The single-band masked images will not be deleted at this time because it sometimes happens that a problem will occur in a STREAM job resulting in non-generation of an image; just in case all four images were not created, one does not want to delete those that were. Besides, after you confirm during a later interactive session that the final four-banded mask image (AK30175.10345.MASKED here) was created, you can easily delete the unneeded duplicate single-banded images. The justifications for creating a single four-banded masked image are (1) that it makes it easy to

remember which image is associated with which image and the origin of each, and (2) the four-banded masked image will be on one store tape, making the retrieval easier and faster and multi-band display much easier.

(21) An IDIMS session history will be produced by the STREAMJOB. In it, the LISTCAT command will generate a list of those images on line with a description of each image for your records. If any problems occurred in the STREAMJOB sequence, you will know exactly where to look and the remaining work to be done.

(22) STORE created images. See comments in step 20.

(23) Ending the IDIMS portion of the STREAMJOB.

(24) The !EOJ command ends the STREAMJOB (EOJ means end-of-job).

(25) Two slashes is an EDITOR command indicating to the computer that you are either through creating lines of text (as here), or desire to make a modification before resuming, etc..

(26) All of these are EDITOR commands. The GATHER ALL command renumbers all lines in increments of one, starting at one. The KEEP jobname,UNN (remember, the jobname is anything you want it to be) names the file in an UNNumbered status; keeping Editor files in an unnumbered status minimizes systems problems. The END command exits you from the Text Editor and returns you to the MPE mode.

(27) Logs you off the system.

(28) Self-explanatory instructions.

CONCLUDING STEPS

The three remaining steps in Water Circulation Digital Enhancement Techniques are: (1) Choice of Colors, (2) Assignment of Colors, and (3) Generation of Photo Products, Analysis of the enhanced photo products is described in an already delivered document titled: "Interpreting Color Enhanced Landsat Single Channel Images of Water Bodies." (Appendix F).

(1) The Choice of Colors.

The choice of colors to use in a Water Circulation Study of the Upper Cook Inlet type can be expedited by

interactively bringing the image(s) up onto the IDIMS display device (color TV) and using the TCC commands to manipulate them. At any rate, you should confirm in advance that the color scheme you contemplate will give you the optimum useful product for your situation. For example, the commands:

```
AK30175.20345[4]>
TCC NEW BLACK O
TCC DKBLUE 1
TCC LTBLUE 2
.
.
.
TCC LTRED 18
TCC WHITE 63
```

Note: When you annotate, make text value 63 and the annotation text will be white when you type in TCC WHITE 63.)

When you have determined the color combinations or color scheme that is most appropriate for you, you can move on to the function COLR (if at NASA/Ames) or DICOTAPE.UTILS, to create color images for generation into photo products. But you should, if you have the opportunity, look at various color combinations on the display device at this stage of the analysis.

There are two basic approaches to take in assigning colors; one I have labeled the Gradational Color Bar Approach and the other I have labeled the Maximum Contrast Color Bar.

The simplest, fastest, and most esthetically pleasing is the Gradational Color Bar scheme. The Gradational Color Bar places the colors in the natural spectral wavelength sequence or its inverse. I used the inverse sequence of Blues, Greens, Yellows, Oranges and Reds in the Upper Cook Inlet Study because the Project Task Monitor thought this made the most pleasing appearance on the MSS 7 image. Using the Gradational Color Bar resulted in a gradual transition (e.g. light blue to dark blue) of colors across the water with little image striping apparent. This approach, while easy to interpret and esthetically very pleasing, obscures details in the water circulation that may be quite important.

The other alternative is to interactively customize on the display device the sequence of colors such that a visual "clash" of adjacent colors occurs across the

water. Be forewarned that this approach visually accentuates not only the fine detail in water circulation but also the striping present; it also may be more difficult to quantify due to the scatter of similar colors across the reference color bar. For detailed work, however, this is probably the better choice of approaches to use.

(2) Assignment of Colors.

Since each IDIMS facility has its own 'customized' arrangement for assigning colors to classified images, it is not practical to list the idiosyncrasies of all of them. A generalized description follows, however.

The function used at NASA/Ames to assign colors to a digital image is COLR: it was the function used to assign the colors in the Water Circulation Study of Upper Cook Inlet. The color bars along the margins of the images were generated using the functions ANNOTATE, MOSAIC, and INSERT. The annotation along the bottoms of the images was generated using the functions ANNOTATE and MOSAIC.

The function COLR used at NASA/Ames is a computer subroutine on IDIMS written by Robert (Buzz) Slye; since it is not a standard IDIMS function, questions about it should be addressed to NASA/Ames/WRAP personnel rather than to IDIMS personnel. It should be noted that the function COLR allows the generation of a larger number of colors than the IDIMS utility function DICOTAPE. DICOTAPE is the "standard" documented IDIMS method for generating a color classified image from a single-banded digital image.

(3) Generation of Photo products.

Once you have used the locally available function(s) to generate a color image, you are ready to generate on the Dicomed or OPTRONIX machine (or whatever system is available to you) the desired photo products.

APPENDIX H

INTERPRETATION AND ANALYSIS: UPPER COOK INLET CIRCULATION STUDY USING LANDSAT IMAGERY

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INTRODUCTION

The currents and circulation in Upper Cook Inlet (Figure 26) have never been thoroughly studied, yet knowledge of the area's circulation would be of great benefit to development planning in the Upper Inlet. Major projects needing this information to adequately evaluate their feasibility and/or impacts include the proposed Susitna Hydroelectric Project and Knik A~m/Turnagain Arm Tidal Power Generation Project.

Study of the Upper Inlet circulation has posed exceptional field data collection difficulties because of the extreme tidal range, fast currents, dangerous rips, and extensive shoals. The intent of the present study is to assess the possibility of utilizing Landsat imagery to assist in deducing or interpreting the circulation based on the distribution pattern of the surface suspended load. Suspended sediment concentrations as high as 1-2 gm/l (1-2 part per thousand) are found in Upper Cook Inlet and provide a potential tracer for current movements. The surface water reflectance registered on Landsat imagery has been shown by previous investigators to closely correspond to the surface suspended load which, in Upper Cook Inlet, is comprised almost entirely of sediments. The distribution of the surface suspended load has furthermore been observed to correspond closely with the surface water circulation in other coastal regions of Alaska.

The National Aeronautics and Space Administration provided essential support for this project. The NASA/Ames Research Center analyzed two Landsat scenes (ID 21288-20253 and ID 30175-20345) using digital enhancement techniques on IDIMS, and furnished this project with the color prints and slides necessary to conduct our analysis. The IDIMS analytical techniques were thoroughly documented (Appendix G) to ensure reproduceability.

METHOD

The analytical technique which we anticipated using at the outset of the project was to:

1. project the 35 mm slides of the IDIMS color enhanced imagery onto base maps, and

2. contour the reflectance (which is a function of the turbidity or relative suspended load concentration) on the base map to provide a relatively accurate composite of the bathymetry, mud flats, and turbidity.

This composite could then be used to accurately compare and analyze the interrelationship between the turbidity, charted bathymetry, mudflats and shoals, river inputs, transport patterns, and possibly other factors.

A variation of this technique was used in an earlier NASA project titled "Sea-Surface Circulation, Sediment Transport, and Marine Mammal Distribution, Alaska Continental Shelf" (Sharma et al., 1974). In that project the positive transparencies of each black and white image were color density sliced with a VP-8 Image Analyzer which incorporated a vidicon camera and color TV. The color TV was photographed with a Pentax Spotmatic camera and the 35 mm color slides were projected onto base maps with a conventional 35 mm projector adjusted to provide the necessary scale. This technique proved to be fairly successful with only minor problems with image distortion or mismatch, due largely to map projections which were not equal area.

Attempts to utilize this technique with the color slides, generated from the system with the present project, encountered a large mismatch when observed when comparing the IDIMS slide to NASA's black and white prints of the same scene. It is presumed that this distortion in the IDIMS digitally enchanced scenes generated for this project represents a need to correct the digital data for satellite system variations such as attitude of the satellite.

This distortion in the IDIMS generated scenes was sufficiently great that it was considered impractical to attempt to overlay the data from the IDIMS scene onto the base map with any degree of accuracy. Because of this difficulty it was necessary to intercompare the turbidity data (provided by IDIMS) with the water depth and other features by means of a careful visual comparison of the imagery and nautical chart.

Additional difficulties were encountered because the dodged black and white prints were not included with the IDIMS products. There was insufficient time to order the prints and no copies were available in Alaska. As we had earlier indicated, the dodged prints are essential for interpretation of the color products. MSS Band 4 in particular is necessary to delineate cloud cover and atmospheric haze.

These data needs were partially fulfilled by products available locally (MSS Band 5 transparencies from the University of Alaska Geophysical Institute and MSS Band 7 standard black and white prints from the Alaska Resources Library), however, the results obtained in using these products were not entirely satisfactory. Specifically the delineation of cloud cover, haze, and mud flats is somewhat questionable because of unavailability of the dodged black and white prints.

Although this alternate technique precluded analyzing the IDIMS products in as accurate a manner as might otherwise have been possible, the analysis did provide significant results. These are described in the following section.

RESULTS AND DISCUSSION

Two Landsat scenes, ID 21288-20253 (8 August 1978) and ID 30175-20345 (27 August 1978), were digitally enhanced on IDIMS. For the two IDIMS color products which were most representative of the suspended load (turbidity) distribution, the data was contoured and drafted to produce Figures 27 and 28, which show the relative suspended load distribution in Upper Cook Inlet on 8 and 27 August 1978. The figures are based on Band 7 (near infrared) which has very little water penetration, and consequently the relative suspended load distributions portrayed by Figures 27 & 28 are representative of only the very near-surface water.

In the northeast half of Upper Cook Inlet, a correlation between water depth and surface turbidity (reflectance) can be observed in a number of areas. Submerged shoal areas appear to correlate relatively well with the turbidity of the overlying water. This is probably largely a consequence of increased turbulance and vertical mixing over shoal areas, which result in an increase in the suspended load concentration at the water surface. For example, the increased turbidity over the shoal west of Fire Island, noted as A in Figures 27 and 28, is apparent even though the water depth over the shoal was in excess of about 15 ft. at the time the imagery was acquired.

Waters overlying the deeper channels generally appear less turbid. For example, the region of low turbidity (B in Figure 28) overlying the channel located north of Fire Island closely corresponds to the bathymetry as seen in Figure 26.

In the southwest half of the Upper Inlet, there appears to be considerably less correlation between water depth and

ORIGINAL PAGE IS OF POOR QUALITY

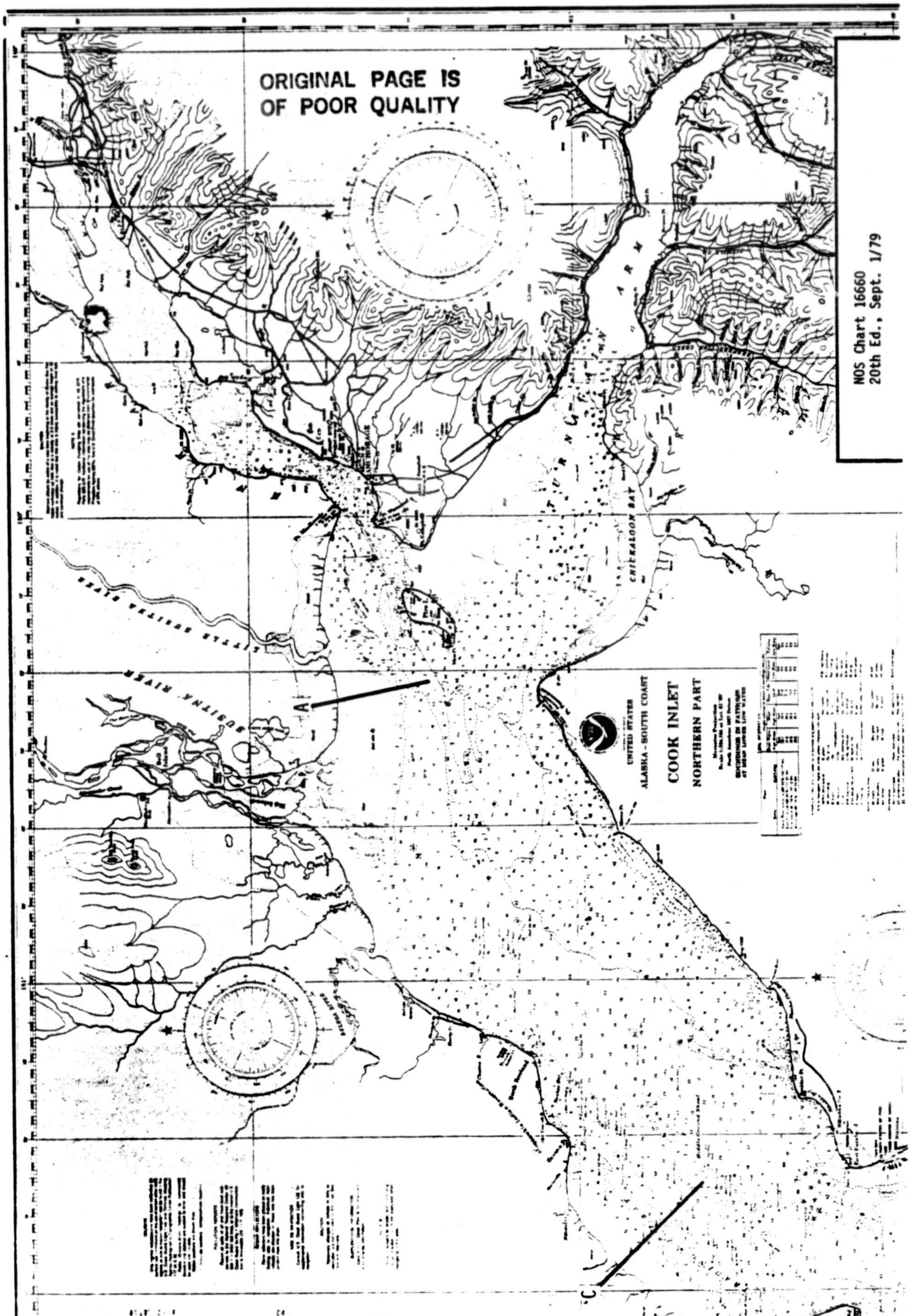

Figure 26. Upper Cook Inlet, Alaska

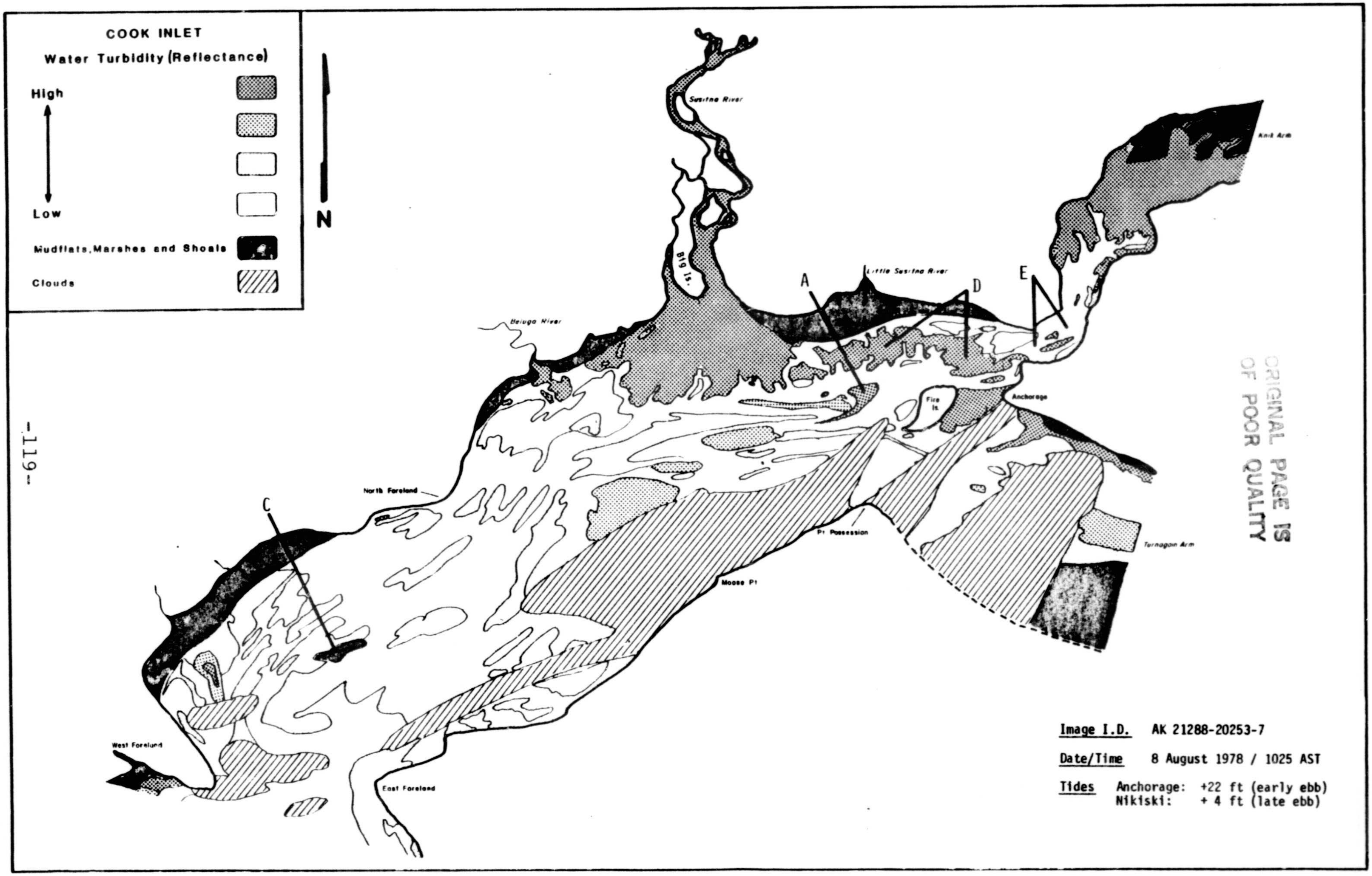

Figure 27. Relative surface suspended load (turbidity) distribution in Upper Cook Inlet on 8 August 1978, based on IDIMS digital enhancement of LANDSAT image I.D. AK 21288-20253-7.

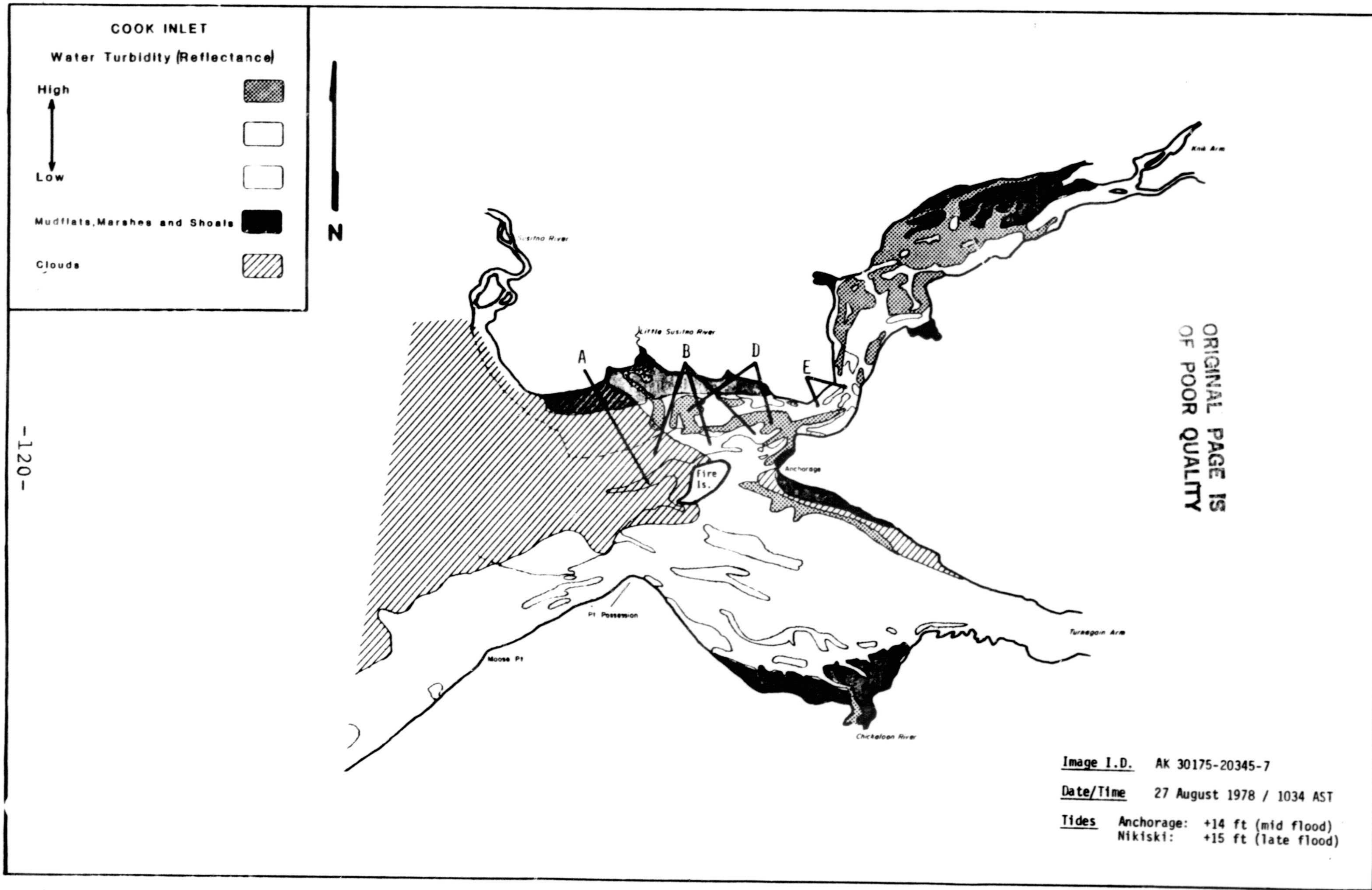

FIGURE 28. Relative surface suspended load (turbidity) distribution in Upper Cook Inlet on 27 August 1978, based on IDIMS digital enhancement of LANDSAT image I.D. AK 30175-20345-7.

surface turbidity with the exception of Middle Ground Shoal (C in Figures 27 and 28).

Although there is considerable cloud interference in both scenes, the surface water suspended load (reflectance) distribution observed in Figures 27 and 28 does not offer any clear evidence or suggestion of a net circulation (net water movement averaged over a number of tidal cycles) pattern in the Upper Inlet. In the absence of a net circulation, the observed turbidity patterns would simply reflect dispersion and mixing resulting from tidal currents. This would support the speculation offered by a number of investigators that circulation in Upper Cook Inlet may consist only of a northeast-southwest oscillation in response to the flood and ebb of the tide. Other Upper Cook Inlet Landsat imagery analyzed by earlier investigators (Burbank, 1974; Gatto, 1976; Sharma et al., 1974) had suggested a possible gyre system in the Upper Inlet in addition to the oscillation produced by the tidal currents. As observed in Lower Cook Inlet (Burbank, 1977), it is also quite probable that the Upper Cook Inlet circulation regime varies in response to variation resulting from such factors as river fresh water discharge, the lunar cycle, and seasonal winds.

The plume of turbid water discharged by the Susitna River is evident (Figure 27) over the extensive mudflats at the mouth of the river. Tidal height at the time of the image is approximately +22 ft., so that most of the mudflats should be submerged in this scene. Beyond the mudflats the Susitna River plume is dispersed rapidly as it reaches deeper water.

Figures 27 and 28 both show relatively high surface suspended loads (indicated by D in the figures) along the northern shore between the mouths of the Susitna River and Knik Arm, whereas a lower suspended load (indicated by E) is observed in the vicinity of the mouth of Knik Arm. Because Knik Arm does not show a surface suspended load at its mouth (area E) as high as that found in the area (D) between the mouths of the Susitna River and Knik Arm, the high suspended load concentration in area D may represent Susitna River water which was carried eastward on the flood tide. However, the high turbidity in area D could also result from vertical turbulence and resuspension of bottom or near-bottom sediments as the currents pass over shoals in the area.

No distinct plume from Knik Arm is observable. The turbid water input from the Beluga River forms a distinct plume which is rapidly dispersed by the tidal currents within a few miles of its mouth.

It is significant to note that the correlation between the charted water depth and the turbidity near the head of the

Inlet was observed even though the scenes were obtained near the time of high tide when the shoal areas were covered by more than 15 ft. of water. This would suggest that imagery obtained near the time of low water might be extremely useful for locating shoals in the vicinity of the shipping channels at the head of the Inlet. Although the surface turbidity would not by itself be sufficient to precisely locate or define a shoal area, the imagery could alter or assist pilots in locating rapidly accreting shoals and other changes in the shipping channels.

SUMMARY AND CONCLUSIONS

The primary purpose of this project was to analyze IDIMS color enhanced Landsat imagery to determine if the imagery would be helpful in deducing Upper Cook Inlet circulation patterns based on the surface suspended load (turbidity) distribution, which is represented approximately by the surface reflectance observed by Landsat. The Susitna River mouth was of particular interest with respect to potential impacts from the proposed Susitna Hydroelectric Project. Analysis of two scenes from August 1978 provided the following results:

1. In the northeast half of the Upper Inlet, a significant correlation was observed between water depth and surface turbidity. This may be useful for monitoring changes in the shipping channels, such as rapidly accreting shoals.

2. The surface suspended load (turbidity) distribution pattern observed in the August 1978 scenes is probably representative of tidal current directions only. These two scenes did not provide evidence to support the existence or assist in the delineation of any net circulation which might occur in the Upper Inlet.

3. Turbid water plumes emanating from Upper Cook Inlet rivers are rapidly dispersed and mixed such that it was not possible to clearly trace river plume trajectories more than a few to several miles from the river mouth. This prevented the use of river plumes to deduce net circulation patterns.

4. The turbidity distribution patterns observed in the August 1978 scenes differ from the distribution patterns observed in other imagery analyzed by earlier investigators. Consequently it will probably be necessary to analyze a large number of Landsat scenes of Upper Cook Inlet to determine the variability of the turbidity distribution and whether there is a typical or normal turbidity distribution which is characteristic of the Upper Inlet.

5. Although this study is inconclusive with respect to delineation of a net circulation pattern in Upper Cook Inlet, it should not be assumed that Landsat imagery cannot be used for this purpose in at least some areas of Upper Cook Inlet. Earlier investigators using other Landsat imagery have found evidence of a net circulation in the southwest half of the Upper Inlet. However, interpretation of the suspended load transport in the northeast half of the Upper Inlet is extremely difficult because of turbulence and resuspension of sediments in

shoal areas, and the utility of Landsat imagery for delineation of net circulation in this region is at best marginal during the summer. It may be possible, however, to use Landsat imagery of winter ice distributions to interpret circulation at the head of the Inlet.

RECOMMENDATIONS

1. Data Processing

   a. The dodged 9.5" x 9.5" black and white prints for MSS Bands 4 through 7 are essential for analysis of all color enhanced products.

   b. IDIMS products should be corrected for areal distortion to facilitate intercomparison of the Landsat imagery with other map products.

   c. Use of similar colors during enhancement of a scene should be avoided. It is extremely difficult to differentiate closely between similar colors.

2. Future Study

   a. The feasibility and practicality of using Landsat imagery to assist piloting vessels through the Upper Inlet shipping channels should be investigated.

   b. The Susitna Hydroelectric Project should investigate the potential for eastward net transport of Susitna River water. Landsat imagery suggest eastward net transport may occur, and if true the increased winter discharge of fresh water from the Susitna Hydroelectric Project could increase ice problems in the Anchorage shipping channels.

   c. Coastal Habitat mapping programs in Upper Cook Inlet should attempt to locate Landsat imagery obtained at low tide for use in accurately delineating the extent of mudflats and shoals.

   d. Analysis of Landsat imagery showing winter ice distribution should be strongly considered as an alternative method for delineation of circulation throughout Upper Cook Inlet.

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APPENDIX I

INTRISCA PROJECT

ONE-DIMENSIONAL EDGE ENHANCEMENTS ON IDIMS: DESCRIPTION, PROCEDURES, EXPLANATION, AND INTERPRETATION

Lindsey V. Maness, Jr.

For maximum precision, sensitivity to subtle local changes, and optimal cost effectiveness, one-dimensional edge enhancements are preferable to multi-dimensional edge enhancements such as Fast Fourier Transforms, data convolution, etc.. The simplicity and utility of the procedures utilized are ideal as an introduction to both edge enhancements and related IDIMS functions. This document is meant to acquaint both the novice and the sophisticated user-analyst with one-dimensional edge enhancements, how to accomplish the enhancements digitally on IDIMS, and the general photo-interpretation guidelines.

I. Description

One-dimensional edge enhancements transform a one-pixel anomaly in the raw data into a two-pixel anomaly in the enhanced image. In comparison, multi-dimensional edge enhancements of three by three matrices transform a one-pixel anomaly in the raw data into a much more subtle and less precise nine-pixel anomaly in the enhanced image.

Additionally, differences in local detector sensitivity calibration (striping) are often of comparable magnitude to the data anomalies, which serves to further obscure the spatial inhomogeneities in the data when multi-dimensional edge enhancements are applied. When operations are confined to within a line (along the X-axis), differences between detector calibrations are not being measured and, therefore, do not appear as anomalies on a one-dimensional edge enhancement image. However, one-dimensional edge enhancements across lines, the Y-axis, XY-axis, X-minus-Y-axis, and their respective orthogonals, do enhance differences in detector sensitivities resulting in image striping.

In the demonstration tasks involving one-dimensional edge enhancements of Landsat data conducted at NASA/Ames Research Center on the X, XY, Y, and X-minus-Y axis, the following general descriptions apply to image quality and usefulness. The X-axis imagery is very clear, easily interpretable, does not suffer from striping and is a compromise between optimal enhancement of cultural versus physiographic features.

XY-axis imagery suffers from moderate striping and enhances cultural lineaments optimally by obscuring physiographic changes in the imagery; this is caused by sampling within slopes with comparable lighting due to the location of the sun to the southeast (in the X-minus-Y direction). On the Y-axis imagery, neither cultural nor physiographic edges have optimal visual enhancement as a result of striping, which can be extreme. The X-minus-Y axis enhances physiographic edges optimally since sampling across the boundaries between well-lit and shadowed areas occurs most frequently using this technique; the identical amount of digital information about cultural lineaments is present as in the XY-axis but is not as apparent since so much more information about physiographic edges is seen on the imagery by the analyst.

The IDIMS functions used in the Alaska (INTRISCA Project) one-dimensional edge enhancements, PLENTER (to de-skew and enter raw data in IDIMS format while retaining image-related files), COPY (to prepare subsets of the data), COPYIRF (to copy image related files from one image to another), ADD (to subtract on IDIMS, use the ADD function), UNITE (to make four single-banded images into one four-banded image), MAP (to add a constant to an image or to stretch the data values to enhance the digital anomalies), CONVERT (to change the data to system-friendly eight-bit byte data in a band-interleaved format), MAGNIFY (to approximate geo-correction), ANNOTATE (to append explanatory text about MSS channels, Scene IDs, etc. to the image), MOSAIC (to append the annotation legend to the image), and DICOMED (to acquire color or black and white photo products) are simple, frequently used, and well-documented. If the function ROTATE had been applied with theta=-11 degrees, just before DICOMED was run, the image would have been oriented to very near true north. Most of the steps described above were performed in a batch (on IDIMS, STREAM) mode to minimize interactive console work. The actual IDIMS functions (with clock, not CPU, time) are presented in the following serial flowchart to document how the Alaska edge enhancements were accomplished on the IDIMS system.

II. Procedures

Total Clock Time Hrs./Mins.	#	IDIMS Function
2:45	1	>PLENTER(SL=1 NL=2340 NS=3480 BANDS=4 LISTDEV=TERM + UPSCALE=1 TAPES=1 SPECTYPE=BB+ SKIPSIAT=NO BAND4FAC=2)>AK30175.20345.RAW
0:50	2	AK30175.20345.RAW(1 1 2340 3297)>COPY>AKXL
0:01	3	AK30175.20345.RAW AKXL>COPYIRF

```
0:50     4   AK30175.RAW(1 2 2340 3297)>COPY>AKXR

0:15     5   AK30175.20345.RAW>STORE

8:00     6   AKXL[1] AKXR[1] SKXL[2] SKXR[2] AKXL[3] AKXR[3] +
             AKXL[4] AKXR[4] ADDSA(FACTORS=1 -1 1 -1 1 -1 1 -1)>+
             AKXRU1 AKXRU2 AKXRU3 AKXRU4

1:50     7   AKXRU1 AKXRU2 AKXRU3 AKXRU4>UNITE(SPECTYPE=BB)>AKXRU

0:01     8   AKXRU1 AKXRU2 AKXRU3 AKXRU4 AKXR>DELETE

4:00     9   AKXRU>MAP(FROM=-127 0 127 TO=0 127 255)>AKXR.TEMP

3:20    10   AKXR.TEMP>CONVERT(OUTYPE=BYTE SPECTYPE=BB)>+
             AK30175.20345.XB

3:15    11   AK30175.20345.XB>HISTOG(NUMBINS=256 CUMHIST=BOTH +
             PICTMEAN=YES DEVICE=LP)

1:25    12   AK30175.20345.XB>MAP(FROM=0 120 127 134 255 TO=0 +
             1 127 254 255)>AK30175.20345.XFINAL

0:01    13   AKXL AK30175.20345.FINAL>COPYIRF

0:01    14   AKXL AKXRU AKXR.TEMP>DELETE

0:15    15   AK30175.2035.XB>STORE

0:45    16   >ANNOTATE>LEGEND

2:10    17   AK30175.20345.XB LEGEND>MOSAIC(PINLINE=1)>+
             AK30175.20345.ANOT

0:01    18   AK30175.20345.XB AK30175.20345.ANOT>COPYIRF

0:15    19   AK30175.20345.XB>STORE

0:25    20   AK30175.20345.ANOT[4 2 1]>DICOMED

0:33    21   AK30175.20345.ANOT>IDTRANS(IMAGENO=1)>

0:15    22   AK30175.20345.ANOT>STORE
```

III. Explanation

The following numerical listing explains the IDIMS functions sequence and procedures shown on the preceding flowchart.

1. PLENTER function was chosen over ERTSENTR because PLENTER retains the image-related C-file, de-skews the image, and adds 1 to every pixel except those created as a

result of image skewing (which are assigned a 0 value); ERTSENTR does none of these things. PLENTER and ERTSENTR are used to reformat raw data from an Earth Resources Observation System (EROS) computer compatible tape (CCT) into IDIMS format. Tapes which have been preprocessed elsewhere probably will have to be entered using another of the enter functions.

If a C-file is appended to the image in IDIMS format, and it is full, the IDIMS function PGC can be used in the final stages to apply a "precision geometric correction" to the image. AK30175.20345.RAW is the image name and translates to Alaska, Scene ID, and type of data. Note that proper image naming conventions, when followed by the user-analyst, can eliminate unnecessary confusion, especially when either more than one person is involved or the analysis occurs over a long period of time.

2. The desired area for edge enhancement is extracted (subset) and named AKXL. AKXL is an acronym for Alaska, X-axis, left side.

3. All image-related files are copied from the raw image to AKXL except for P (picture) and H (history) files, which are assigned permanently to the image as long as it remains in the user catalog. In edge enhancement operations, the only significant file to be copied is the C-file (see 1 above). If COPYIRF is not run, the only files associated with the image are the P and H files. To get a list of on-line files, the command "LISTF @.userid,2" may be typed in MPE mode. The MPE mode is active when the computer prompts the user terminal with a colon (:), as when logging on or off the HP3000 system.

4. A subset area with the same line and column dimensions but offset one to the right from AKXL along the X-axis is extracted and named AKXR. AKXR is an acronym for Alaska, X-axis, right side. The existence of two images offset one (or more) pixels from each other allows numerous types of comparisons to be made on IDIMS: however, only one of these, subtractions, is discussed in this document. The offset can be made along any axis and for any distance but the most common offsets are the X, XY, Y and X-minus-Y axes, as described on page 1, paragraphs 3 and 4.

5. The raw image is no longer needed for edge enhancement purposes so it is stored in case of future need. Images are brought back on line (with all image-related files) much more quickly from an IDIMS store tape than in any other form. If it is not possible to STORE the image at the facility, for administrative reasons, a good alternative is to IDTRANS (see step 21) and then delete the raw image.

6. Image AKXR is subtracted from AKXL, one channel at a time, starting with channel one and progressing to channel four. Channel one is the same as Landsat multi-spectral scanner (MSS) 4; channel two is MSS 5; channel three is MSS 6; and channel four is MSS 8. The FACTORS parameter includes one number for each image specified to the left of the word ADD and performs operations in pairs. It multiplies the appropriate FACTORS numbers by the appropriate images, pixel-by-pixel, and then adds the result in a pairwise fashion. Obviously, multiplying the second number by minus one and adding to the first is equivalent to a subtraction of the second image from the first. The number of output images is always equal to exactly one-half the number of input images or the job will not run. The output images are named AKXRU plus the channel number. The AKXRU1 acronym, for example, means Alaska, X-axis, REAL-form unstretched data of channel 1. In terms of CPU time, clock time, disc-space and tape-length utilized, it is most unfortunate that a subtraction of byte data on IDIMS generates a REAL-form image rather than an INTEGER-form image. REAL-form data are VERY system unfriendly, INTEGER-form less so, and BYTE-form most system friendly on the IDIMS/HP-3000.

7. The subtracted images are UNITEd to form a single, four-band image to minimize processing redundancy. If the work is done batch (termed STREAM on IDIMS), it is preferable to do all operations up to and including step number 10 prior to uniting the images since a UNITE of byte data is both faster and requires less disc space than data of REAL-form.

8. The preceding intermediate-stage images are deleted as soon as possible to minimize load on the disc. Note that image AKXL is kept on-line to transfer image-related files in step 13.

9. The MAP function of IDIMS is used, in this example, to add a constant, 127, to the data so that conversion to BYTE-form can occur. Please note that the MAP function on IDIMS has nothing whatsoever to do with maps; it refers strictly to what are more commonly termed "data stretches" on other remote sensing systems. A topographic quadrangle map or other hard-copy map is referred to as a "spatial map" in IDIMS documentation. The MAP function on IDIMS creates a look-up table and, in effect, instructs the computer thus: "Every time you see this number, change it to the specified new number." The (data stretch) MAP function is one of the most used in IDIMS; it is a multi-purpose function.

10. The previously stretched (step 9) data, all Dn values (digital number values) which fall between 0 and 255 (eight bit byte data) are converted to system-friendly band-interleaved byte data.

11. The data are histogrammed to determine the spread about the peak of the mode, preparatory to step number 12.

12. A stretch, one Dn removed from both sides of the base of the mode along the tail, is usually at or near optimum. In the example given, the mode ends and tails begin at Dn values of 121 and 133; therefore, the parameters specified in the stretch are 120 and 134. The actual input parameters are (FROM=0 120 127 134 255 TO=0 1 127 254 255): in this example, a 0 remains a 0, all numbers between 1 and 119 become either 0 or 1 depending on whether the number is closer to 0 or 120, a 120 becomes a 1 in the output image, values between 121 and 126 (inclusive) become the interpolated values between 2 and 126, 127 remains the same value, and so forth. Note that 127 is by far the most common value since that is the Dn of the highest point on the histogram; this relationhsip is true because before 127 was added to the image in step 9, the value of these pixels was 0, the most common value when subtracting adjacent pixels.

13. The image-related C-file is copied onto the final X-axis edge-enhanced image. The function PGC could now be run to resample and rotate to true north the image (if the C-file is not empty) such that a given number of pixels either horizontally or vertically covers the same distance on the ground. Since each resampled pixel covers the same distance vertically as horizontally, each pixel after the PGC function is run becomes a square pixel.

14. Images not needed are deleted.

15. The byte image which hasn't undergone any enhancement stretching is stored. If at some later date, a different data stretch or annotation is desired, it is an easy matter to retrieve this image with the command: AK30175.20345.XB>LOAD.

16. An annotation is created for appending to the final image. Information in the annotation should include MSS band(s), state or country, Scene ID, project title, etc.. Since the annotation procedure would require a lengthy explanation and is best done interactively, interested users are referred to IDIMS documentation.

17. The annotation legend is mosaicked to the image.

18. The image-related files are copied onto the new annotated image (see step 2).

19. The un-annotated X-axis edge-enhanced image is stored.

20. A three-channel annotated image is recorded on film by the DICOMED File Recorder. In the example given, [4 2 1],

channel 4 (MSS 7) is portrayed as red, channel 2 (MSS 5) as green, and channel 1 (MSS4) as blue. Single-band black and white images can be created by specifying only one band in the channels parameter. The default, if no bands are specified, is [1 2 3].

21. An IDTRANS tape of the annotated X-axis edge-enhanced image is acquired. If there are system (or other) problems that result in the deletion of the image just created, the image will not have to be recreated from scratch; the command >IDENTER(IMAGENO=1)>AK30175.20345.ANOT will bring it back on line from the IDTRANS tape. If IDENTER is used, the command AK30175.20345.ANOT>FIXHIST should be run immediately afterwards to append the stored H-file (history file) to the image, which will minimize catalog errors and cut down on unnecessary work by systems personnel. If FIXHIST is not run, an HX file will be left on line on the user account and will have to be purged by system personnel; in addition, the past processing history of the image will be lost to the user.

22. The annotated X-axis edge-enhanced image is stored. It is also possible to store the images created during the normal END sequence on IDIMS. IDIMS prompts for every online image asking for instructions about whether to delete (D) or store (S).

IV. Interpretation: Analysis Principles

Several phenomena are either of analytical interest or unique to one-dimensional edge enhancements: these phenomena are an apparent relief illusion, enhancement of linear features relative to axis direction such that identical features appear different as a function of orientation, pronounced enhancement of subtle linear or curvilinear anomalies (as in water body "fronts"), the influence of the MSS bands upon enhancement, etc..

1. Apparent Relief Illusion.

The apparent relief on imagery, whether appearing as a deep cleft (roads on MSS 5) or as a blister or depression (lakes on MSS 7), is caused by the gross contrast in brightness of the two immediately proximal lines along the edges. A photographic enlargement of the left shoreline of lakes displays a very bright outer line and a dark inner line; the opposite relationship exists on the right side of the lakes. The very bright ring on the left side of water bodies is caused by the difference (a positive number) in brightness values between vegetation (bright) and water (dark) on MSS 7 being greatly enhanced. On the right side of lakes the difference (a negative number) between water

(dark) and vegetation (bright) becomes a dark line after enhancement. That the relief effect is an illusion can be verified by looking at large rivers with variable sediment loads. On the edge enhanced imagery, the rivers appear to contain pronounced ridges and valleys. The presence of rivers is enhanced on MSS 6 and 7 due to, in part, the illusion of relief created by adjacent light and dark strips on the edge enhanced imagery.

2. Axial Direction Enhancement.

According to their orientation relative to axial sampling direction, features such as roads, urban/suburban areas, rivers, and glaciers exhibit significantly different aspects and textures.

Roads, when sampled orthogonally, are enhanced optimally because of the increased probability of fewer local edge pixels (see page 1, paragraph 2). As the axis direction becomes more similar to the road direction, the edge effect decreases; when the axis direction parallels the road, the road disappears from the enhanced image.

Roads, railroads, trails, powerlines, pipelines, seismic survey lines, and other linear cultural features can be differentiated through careful analysis of different MSS single-band (black and white) or multi-band (color) photoproducts, by cross referencing with published map sources, and by field checking.

Roads and railroads, while appearing very similar on all four MSS bands, can be differentiated somewhat on large scale photographic blow-ups by analyzing the branching patterns of the suspected transportation arteries. Railroads generally have a much simpler and more smoothly curved aspect than roads. Unfortunately for photointerpreters, roads and railroads often follow the same course, side by side.

Roads and trails can be difficult to differentiate with absolute accuracy on single-band Landsat one-dimensional edge enhanced imagery but can be mapped with a fair level of confidence with black and white MSS 4 and 5 photo products. MSS 5 delineates roads and trails quite well and, while the intensity of the lines may be suggestive of the relative sizes of the transportation arteries, MSS 5 alone is often not sufficient to differentiate roads from trails. A comparison with MSS 4 will often remove much of the confusion since most smaller roads and trails either disappear entirely or become more subtle than the larger roads in the area.

Transportation arteries can usually be differentiated from powerlines, pipelines, and seismic survey lines by analysis of spatial patterns and by a careful comparison of the features of MSS 5 with those of MSS 6 or 7. Non-road linear features generally have vegetation growing within the edge pixels, unlike transportation arteries, which leads to a (sometimes pronounced) difference in appearance on color imagery. Powerlines cross rivers and marshes without bridges, do not have complex networking, and generally go from community to community in as near a straight line as possible. Pipelines generally end at a river or outlet to the sea, may go to a refinery, don't necessarily go directly from community to community, usually have en-route pumping stations, do not necessarily go in a straight line, and have fairly simple networking. Seismic survey lines' spatial patterns vary considerably according to age, area of the world, geological and property considerations, company doing the survey, etc., but can usually be differentiated from other linear features with a high level of confidence by an interpreter with knowledge of the area's petroleum.

Similarly, and more noticeably, urban/suburban areas generally have a very distinctive pattern of slightly inclined parallel lines. If on an X-axis enhanced image, the lines trend in a somewhat Y-axis direction; if on an Y-axis enhanced image, the lines trend in a somewhat X-axis direction, and so forth. This effect is an extension of the enhancements of roads, described above.

Rivers, when sampled orthogonal to flow direction, enhance differences in suspended sediment as a function of flow regime across the river. A vector component modelling of water flow downstream between boundaries could be inferred with proper on-site calibration measurements. Similarly, when sampled parallel to flow direction, differences in water bodies between fronts are enhanced as a function of downstream flow regime; in this case, a vector component model of water flow across the river between boundaries could be inferred with sufficient on-site calibration measurements.

Glaciers, when sampled orthogonal to flow direction, have medial moraines enhanced (parallel straight lines) and crevasses obscured; when sampled parallel to flow direction, have crevasses enhanced (chevron shapes) and medial moraines obscured; and, if neither solely orthogonal nor parallel, are influenced by both medial moraines and crevasses as a function of the sine of the angle of the sampling direction axis with the glacier.

FIGURE 29. One-dimensional edge enhancement, MSS 6

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3. Enchancement of Subtle Curvilinear or Linear Anomalies

Subtle curvilinear anomalies, whether they be ultimately caused by changes in cultural influences, vegetation, water clarity, geology, etc., are made more apparent by enhanced difference imagery. Whereas only a few pixels of change scattered randomly might not attract a photointerpreter's eye, when the same amount of change is arranged in a coherent pattern, the result is a strikingly obvious feature due both to differences with surrounding pixels and to similarity with other pixels of the curvilinear anomaly. This is true whether the enhanced differences reflect changes within or between vegetative, hydrological, geological, cultural, or other groupings. The boundaries between groupings as shown on the enhanced difference images (one-dimensional edge enhancements) display real boundaries between ecozones, water types, soil types, geology, etc.; however, roads and cultural features may be only man-made boundaries across an ecozone, water type, etc..

4. Optimum MSS Band Choice for Specific Purposes.

MSS 4 and 5 are most useful for mapping road networks and cultural features. While MSS 4 shows roads with less visual clutter than MSS 5 due to less enhancement of water boundaries on MSS 4 than on 5, MSS 5 is the preferred choice since roads and cultural features are sharper, clearer, and more enhanced than on MSS 4. Presence or absence (relative) of plants are a significant factor in the sharpness of MSS 5 due to the inverse relationship between chlorophyll and brightness (see IV.3,paragraph 5). The edge enhanced imagery can be used for updating maps with a Zoom Transfer Scope. Probably, at least in information transfer activities, the greatest use of edge enhanced imagery will be in the field of cartography as a support to land use planners.

MSS 6 and 7 display changes in vegetation type and cover (ecozone bounaries) very well.

MSS 5, 6, and 7 display water boundaries based upon variable suspended sediment load quite well.

MSS 4 and 5 are useful for mapping marsh/water boundaries and give some indication of the boundary between bottom and water column reflection.

MSS 4, 5, 6, and 7 are all useful in glacier studies. The bands can be used either singly as black and white images or in combination as color photo products. Different types of ice-snow pack at the heads of glaciers can be differentiated using color photo products; it is hypothesized that these

colors reflect differences in mega-roughness, recrystallization, etc..

V. Conclusion

One-dimensional edge enhanced imagery can be very useful for many remote sensing applications. The boundaries between vegetative ecozones, water bodies, glacial features; and the precise delineation of cultural features, especially roads; can often be accomplished using the differencing techniques described in this document. As in other remote sensing techniques, different MSS bands enhance differently and the imagery derived must be evaluated and used with proper precautions and knowledge of the nature of the data to avoid incorrect conclusions. Furthermore, the imagery should be used in conjunction with as many other types of supporting information as possible to maximize the probability of correct conclusions.

The different types of one-dimensional edge enhancements each have their own distinctive advantages and disadvantages. A good compromise of possible axes with minimal noise is the X-axis. The XY-axis is best for displaying cultural features with the least possible influence from physiographic variations but suffers from across-detector striping. The X-minus-Y-axis is best for delineating physiographic variations but suffers from cross-detector striping. The Y-axis suffers the most visually from striping of the imagery.

The flowchart of IDIMS functions with explanations should be especially useful to user-analysts interested in creating edge-enhanced imagery. Although the software functions listed are IDIMS, equivalent programs exist on most other remote sensing systems; consequently, the processes described in this document have general applicability.

APPENDIX J

STREAM CORRIDOR PHYSIOGRAPHY OF THE SUSITNA RIVER VALLEY, ALASKA
Final Report

NASA-AMES Research Center Consortium
Agreement #NCA2-OR020-001

in conjunction with the
Alaska Department of Fish and Game

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ABSTRACT

Floodplains in the vicinity of a stream form a corridor which is a primary habitat zone. Knowledge of surficial geology along this corridor will provide a data base to aid land-management decisions.

Generally, streams in the Susitna River Valley are incised into glacial deposits and are braided and sediment ladened. Floodplains and terraces develop as the streams migrate, downcut and deposit alluvium. The floodplains are divided into four categories based on surface morphology including presence of channels or sloughs, density and type of forest cover, and proximity to height above stream channel(s). These divisions include active, partly active, infrequently active and abandoned floodplain surfaces.

A traverse from the existing stream channel to the limit of the floodplain demonstrates a slight increase in elevation, increase in the density of the forest canopy, a decrease in number of sloughs and abandoned channels, and a gradation from deciduous to coniferous forests. This trend parallels a decrease in flood susceptibility away from the stream.

INTRODUCTION

The land surface in the vicinity of a stream is a primary habitat zone because of its proximity to water, shallow water table, and gently, sloping terrain. The purpose of this project is to study and map the landforms within a corridor along select streams in the Susitna River Valley. The results will provide land managers with an initial data base to establish riparian management zones or buffer zones to protect fish and wildlife and their habitats from disturbance or damage.

A secondary purpose is to compare the minimum size of floodplains and number of floodplain categories derived from aerial photography to that derived from Landsat imagery (see Appendix).

Landforms are studied and mapped along the Yenta, Susitna, Skwentna, Kahiltna Rivers and Lake Creek in the Susitna River Valley. The results of the project are displayed on 17 USGS topographic quadrangles (scale 1:63,360), including Tyonek B-2, C-1&2, D-1 thru D-6 and Talkeetna A-1 thru A-4 and B-1 thru B-3.

PHYSICAL SETTING

The Susitna River Valley is located in southcentral Alaska northwest of Anchorage (Fig. 29). The valley grades southward to sea level at Cook Inlet and is bounded by the Talkeetna Mountains on the east and the Alaska Range on the north and west. These mountains hinder the northward migration of storms from the north Pacific Ocean, producing 74 cm (29 inches)* of precipitation annually (Rieger, 1979), the largest amount of precipitation in the state excluding areas immediately adjacent to the coast.

Major streams within the study area include the Susitna, Yentna, Kahiltna, Chulitna, Tokositna, and Talkeetna Rivers. The Susitna River, which is the largest in the area, drains southward into Cook Inlet. Glaciers including the Dall, Yentna, Kahiltna, Lacuna, Tokositna, Ruth and Eldridge are located in the nearby Alaska Range at the headwaters of rivers and several subordinate tributaries.

Numerous south trending lakes, wetlands and forested ridges of low relief are typical on the valley floor. Most of the present topography has resulted from glacial, glaciofluvial and fluvial processes (Dean, 1980).

Transportation corridors include the Parks Highway and the Alaska Railroad along the eastern margin of the study area. A secondary road to Petersville and surrounding mines traverses the central portion of the area. Some agricultural, timber harvesting, and mining enterprises are located near Talkeetna. Lode and placer mining operations are active in the hills and mountains surrounding the valley. The minerals or

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*Measurements from the U.S. Weather Service station in Talkeetna, Alaska.

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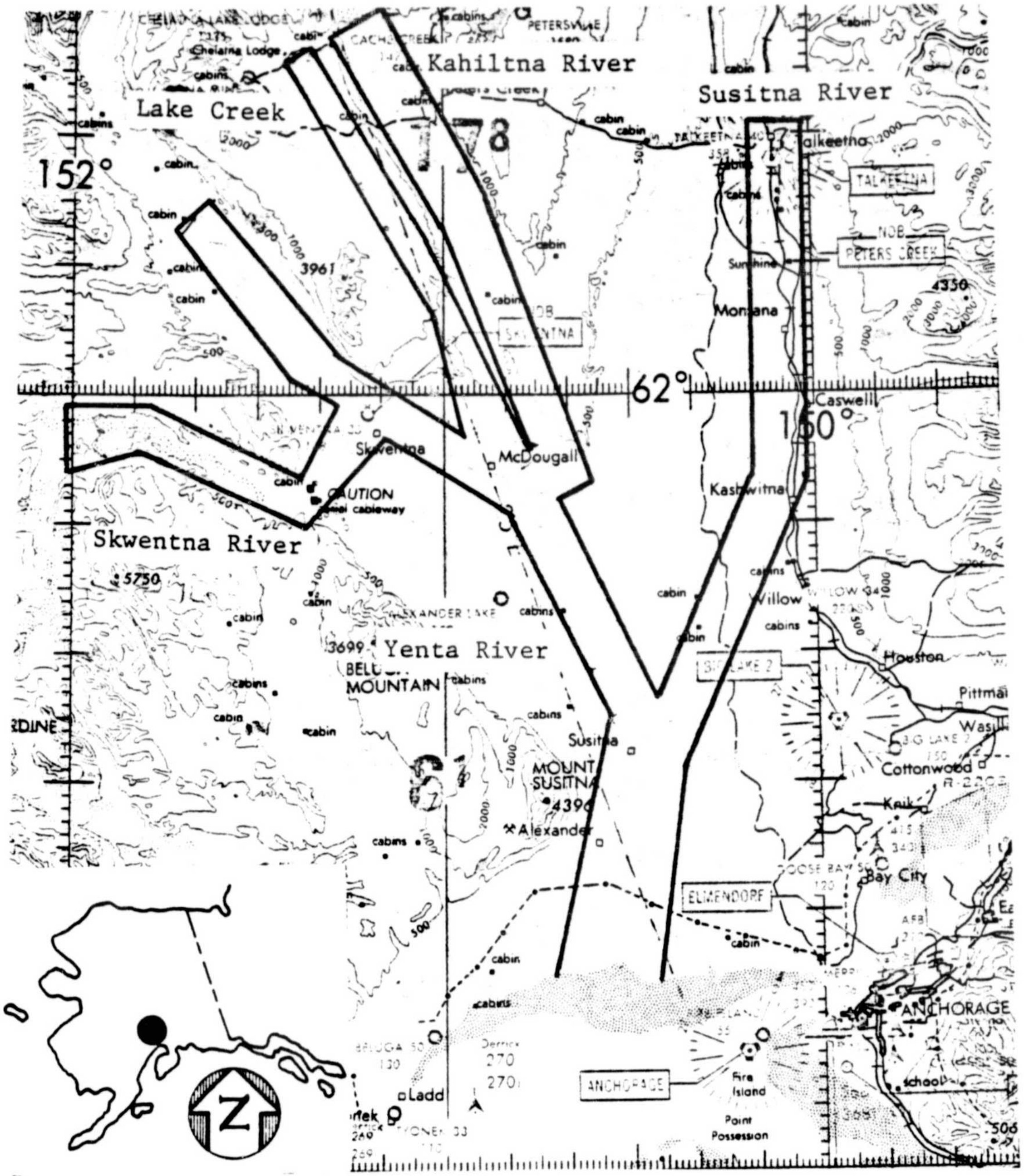

Scale 1:1,000,000

Figure 29: Location of stream corridors in the Susitna River Valley.

elements being mined include molybdenum, copper, chromium, gold, uranium, platinum, tin coal and thorium (Reed and others, 1978).

The region is generally sparsely populated. Clusters of small settlements occur along the Parks Highway especially in the vicinity of Willow and to the south where newly developed subdivisions are prevalent. These subdivisions reflect the pressure for land development along the Parks Highway.

REGIONAL SURFICIAL GEOLOGY

The surficial geology of the Susitna River Valley is dominated by glaciation (Caulter, and others, 1965, Reger, 1976). This area is a trough into which mountain glaciers and drainages from the surrounding Alaska Range and Talkeetna Mountains are funneled.

At least five glacial advances (Nelson and Reed, 1978) have altered the landscape in the Susitna River Valley:

Glacial advances in the Cook Inlet Basin.

Glaciation	Age	Sources
Alaskan	200-4800 yrs. ago[1]	(Nelson & Reed 1978)
Naptowne	6,000-30,000 yrs ago[1]	(Péwé, 1975)
Knik	38,000-65,000 yrs ago[2]	(Karlstrom, 1964)
Eklutna	25,000[1]-110,000[2] yrs. ago	(Karlstrom, 1964)
Mt. Susitna	Pre-Illonian	(Karlstrom, 1964)

The Mt. Susitna glaciation is the oldest and most extensive glacial advance documented in the Susitna River Valley by Nelson and Reed (1978) and in the Cook Inlet basin by Karlstrom (1964). Each successive glaciation was less extensive. The Mt. Susitna and Eklutna Glaciations completely filled the Susitna Valley and Cook Inlet basin, but during the

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[1] Carbon-14 date

[2] Boulder count date (estimated)

Knik and Naptowne Glaciations coalescing glacial lobes in valleys did not completely fill the basin (Nelson and Reed, 1978). The Alaskan Glaciation was generally confined to narrow mountain valleys where end moraines were commonly deposited at the confluence with broader valleys.

The Susitna River Valley contains landforms that resulted from glacial, fluvial, lacustrine, periglacial and paludal processes. During Pleistocene glacial advances bedrock was scoured and debris was transported and deposited by the glaciers and streams. Most of the present topography on the valley floors resulted from the southward advance of the Naptowne glaciation (Nelson and Reed, 1978) which terminated between McDougall and Talkeetna (Karlstrom 1964).

After retreat of the Naptowne glaciers, streams in the Susitna River Valley incised the glacial drift, attempting to re-establish a lower gradient stream profile by transporting eroded material downstream and redepositing it below the terminus of the Naptowne advance. Erosional and depositional processes have resulted in incised stream channels in the northern Susitna Valley and the aggradation of alluvium in the valley south of the limit of the Naptowne Glacial advance.

MATERIALS AND METHOD OF INVESTIGATION

The investigation utilized color-infrared aerial photography, Landsat imagery, USGS topographic maps and aerial and ground verification procedures. NASA aerial photography acquired in 1974, 1976 and 1977 at the scale of 1:120,000 was the primary data source for interpreting and mapping landforms. Landsat images were used to obtain an understanding of regional relationships of landforms.

Landform interpretations were performed through a mirror stereoscope with a X3 magnification lens and the results were mapped on an overlay. The overlay was displayed and enlarged through a vertical projector onto the mylar topographic maps so that the map units could be transferred to the map base. Mylar copies of USGS quadrangles at the scale of 1:63,360 were used as a final map base.

DESCRIPTION OF MAP UNITS

Glacial Landforms

Deposits in the Susitna River Valley are composed of unconsolidated glacial drift. Drift is composed of unsorted silt, sand, gravel, cobbles and boulders (till) and is intermixed with stratified silt, sand and gravel of fluvioglacial origin.

The resulting landforms include undifferentiated hummocky terrain (d), fluted till ridges (r), zones of standing water ($\underline{\psi}$), eskers (e) and outwash fans (ow). All of these map units are located on the Susitna Valley floor beyond the floodplains (Table 18).

The undifferentiated hummocky terrain (d) is composed of glacial drift which protrudes above the surrounding terrain. Depressions or kettles are typical on the surface and trap surface water. Segmented, abandoned drainage-channels traverse the drift sheet. These drainage channels are remnant of previous drainges and often contain standing water. Vegetative growth on the drift consists mostly of deciduous and coniferous forests. In some localities in the vicinity of Talkeetna, eolian sand blankets the drift deposits.

Fluted till ridges (r) parallel the direction of glacial movement. Ridges have low relief and are better drained than the lower surrounding landscape as indicated by deciduous tree growth.

Extensive areas of standing water ($\underline{\psi}$) lie between fluted till ridges and drift deposits. The terrain is low and flat with small undifferentiated deposits of drift scattered throughout. Poor drainage is a result of a low gradient and the impermeable till. Discontinuous permafrost is suspected in swampy areas.

Table 18. Landform map explanation.

fa	- active floodplain
f_1	- party active floodplain
f_2	- infrequently active floodplain
f_3	- abandoned floodplain
fd	- undifferentiated floodplain
tr	- terrace(s)
	- standing water
ox	- oxbow
d	- undifferentiated, hummocky terrain composed of till and fluvioglacial deposits
r	- fluted till ridge
ow	- glacial outwash fan
e	- esker
	- prominant scarp
bs	- scoured bedrock
ac	- alluvial cone
af	- alluvial fan
al	- undifferentiated landscape composed alluvium and colluvium
cl	- coastal lowland
be	- beach ridge(s)
s	- sand or silt dune
sd	- sparse undifferentiated dunes
	- incised stream
	- subordinate drainage channels with standing water
?	- map unit needs further field verification

Eskers (e) and remnant outwash (ow) fans occur in some areas. They consist of fluvioglacial deposits which are exellent sand and gravel sources and are well drained. Deciduous forests typically grow on these surfaces.

Along the margins of the valley the surrounding mountains have been scoured by glacial advances. Ice-scoured bedrock (bs) is often blanketed by a thin layer of till. At lower elevations alluvial cones (ac) and fans (af) extend onto the valley floor.

Fluvial Landforms

Streams in the Susitna Valley are typically incised into the landscape reworking the glacial drift and depositing stratified silt, sand and gravel as point bars, islands, overbank deposits or channel fill forming floodplains in the vicinity of the streams.

The floodplains are divided into six categories: active (fa), partly active (f_1), infrequently active (f_2), abandoned (f_3), terraces (tr), and undifferentiated (fd).

Active floodplains (fa) include the existing stream channel(s), prominent sloughs, recently abandoned stream channels, sand and gravel bars, vegetated and unvegetated islands. Adjacent shore areas include exposed silt, sand and gravel deposits or are with standing water. Vegetation includes uncrowded deciduous forests, typically cottonwood, with a broken canopy and willows. Understory is sparse in some areas.

Partly active floodplains (f_1) are intricately laced with subordinate sloughs and drainage channels usually connected to the dominant stream. These channels contain flowing or standing water, or swamp deposits. The floodplain surface is vegetated by mature mixed deciduous

forests which generally are uncrowded and have broken canopies. The floodplain surface may extend several feet above the normal stream stage.

Infrequently active floodplains (f_2) are dissected by abandoned channels and sloughs, which often are not connected to the parent stream. A few oxbows (ox) are also present. The floodplain surface is vegetated by mature deciduous and mixed forests and is slightly elevated. These forests in contrast to forests on more active floodplains, are generally denser and the canopy is only occasionally broken.

Abandoned floodplains (f_3) have few readily apparent channels, oxbows or sloughs. Coniferous forests tend to prevail and the forest canopy is dense and not usually broken. Areas of standing water are minimal or absent.

Terraces (tr) are remnant floodplains at higher elevations than other floodplain categories and indicate a former floodplain level. They are separated from present floodplains by steeply sloping scarps and are predominantly vegetated by coniferous and mixed coniferous and deciduous forests with a dense, unbroken canopy. Standing water is minimal to non-existent. Often several levels of terraces are included within one map unit.

The undifferentiated floodplain (fd) classification is used along subordinate streams and is generally less than 300m (1000 ft.) wide. Stream flow is often restricted between steep banks. Previously described floodplain divisions are included within this unit and are distinguishable on the photography but too small to be delineated.

Delta-Plain Landforms

In the southern portion of the study area where the Susitna River empties into Cook Inlet aggradation rather than downcutting is dominant. This results in the deposition of large quantities of alluvium and hence more expansive floodplains than to the north. Landforms include coastal lowlands (cl), beach ridges (be) and dunes (s & sd).

Generally, the surface is mapped as coastal lowlands (cl). The area is low, near sea level, and very gently sloping. Standing water is prevalent in many areas and mudflats are extensive during low-tides.

Coastal lowlands and the floodplains bear beach ridges (be) along the coast and eolian dunes (s & sd) further inland. Typically, beach ridges are defined as subparallel ridges of sand, shell or pebble generally varying in amplitude from a few inches to many feet (Davies, 1968) and mark former shorelines. In the study area these ridges support deciduous vegetation which contrasts with the surrounding vegetation on the coastal lowlands.

The eolian dunes are wind deposited ridges composed of vegetated sand and silt and encroach upon areas of standing water. The (s) designation refers to individual dunes and the (sd) designation refers to dune complexes which are typically separated by areas of standing water.

DESCRIPTION OF STREAMS

Susitna River: The Susitna River extends from Susitna and West Fork Glaciers in the Alaska Range to Cook Inlet and most streams in the Susitna Valley drain into this river. That portion of the river in the vicinity of Talkeetna and south to Cook Inlet is included in the study area.

The associated floodplain of the Susitna River is broad and the stream is extensively braided. Islands composed of exposed silt, sand, and gravel are numerous but often temporary while vegetated islands are more stable. The floodplain is divided into five categories: active, partly active, infrequently active, abandoned and terraces. Scarps often border the floodplain north of Willow but from there south the floodplains become very broad with standing water and grade into coastal lowlands (Krebs, and others, 1978 and 1978b). Windblown silt and sand is typical on the coastal lowlands, and dunes in the area are vegetated which indicates some degree of stability. The Susitna River is susceptible to glacial outburst floods north of the Parks Highway crossing (Post and Mayo, 1971).

Yenta River: The Yenta River extends from the Yenta, Lacuna and Dall Glaciers to the Susitna River and is moderately braided with braiding decreasing downstream. Floodplain categories predominantly include: active, party active and infrequently active. The floodplains are broadest near the headwaters and narrow downstream and include many vegetated islands. Areas with standing water are numerous and most extensive in the upper reaches. The Yentna River is susceptible to the effects of glacial outburst floods upstream from the confluence with the Skwentna River (Post and Mayo, 1971).

Kahiltna River: The Kahiltna River is a braided stream which extends from the Kahiltna Glacier to the Yentna River. Near the headwaters, the floodplain is broad with extensive areas of standing water and is divided into active and partly active categories. Downstream, the floodplain is divided into active, partly active and infrequently active categories with many terraces along the margins. The active floodplain becomes very narrow such that in some areas only the stream channel is present. The Kahiltna River is susceptible to the effects of outburst floods near Kahiltna Glacier (Post and Mayo, 1971).

Skwentna River: The headwaters of the Skwentna River are located in the Alaska Range where glaciers contribute water to many subordinate tributaries. The portion of the stream east of Porcupine Butte to the confluence with the Yentna River is included in the study. The floodplain divisions include active, partly active, infrequently active and abandoned, with few terraces evident. Generally, the floodplain is wide but constrained between glacial-scoured, mountain slopes in its western portions but to the east the floodplain is very broad at its confluence with the Yentna River. Extensive areas of standing water are present east of the Old Skwentna Road House. The stream is susceptible to glacial outburst floods upstream from the Old Skwentna Road House (Post and Mayo, 1971).

Lake Creek: Lake Creek drains Chelatna Lake into the Yentna River and is not glacial fed. The associated floodplain is narrow and incised into the glacial landscape especially along a portion centrally located between its headwaters and confluence with the Yentna River. Most of the floodplain is classified as undifferentiated with many terraces along the margins. The meandering stream becomes braided near its confluence with the Yentna River and is the only stream in the study which is clear of suspended sediment.

DISCUSSION

The floodplain classification is based on landform and vegetation including the existence of stream channels and their relationship to the parent stream, proximity to height above the dominant stream channel, density of vegetative canopy, and type of vegetation. Ideally, floodplain categories geographically progress from active in the immediate vicinity of the existing stream to party active, infrequently active, abandoned and terraces at the farthest extent (Figure 30).

Susceptibility of floodplain surfaces to flood events, decreases away from the active floodplains, as indicated by the landforms and variations in vegetation. In the vicinity of the stream surfaces have numerous active and abandoned stream channels which are typically connected with existing stream channels. The presence of these channels gradually decrease on floodplain surfaces away from the stream until they are non-existent. Those abandoned channels furthest from the stream often have no obvious relationship to existing stream channels. These channels indicate former positions of the active floodplain in the recent past. Height of floodplain surfaces slightly increase away from the stream channel as expected.

The active floodplain is sensitive to migrations of stream channels and fluctuation in stream discharge. Abandoned channels on this surface become active during increase discharge phases, likely annually and land surfaces are often flooded.

The partly active floodplain has numerous abandoned channels which also become active during flood events, but not necessarily annually. The land surface is subject to flooding during flood stages greater than annual high water.

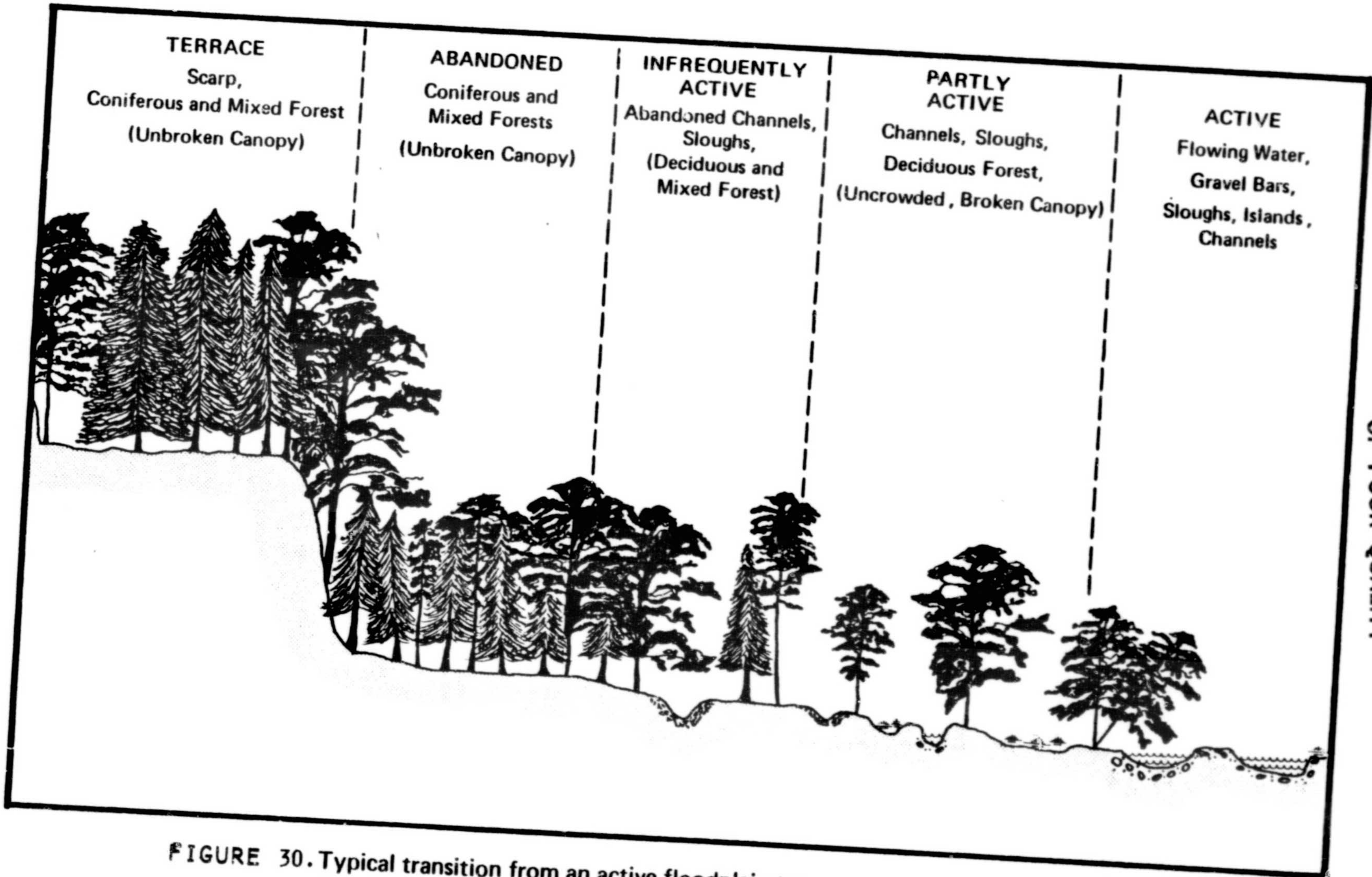

FIGURE 30. Typical transition from an active floodplain to a terrace. Dominant characteristics of each are listed.

On the active and partly active floodplains, cottonwood forests are typical, often with relatively sparse understory consisting of willows, especially along the Susitna River. These forests tend to prevent erosion of fine grained materials by dissipating the higher velocity of floodwater and thus inhibit the transport of coarse material. Studies of the Missouri River (Schmudde, 1963) also indicate that scouring of channels or beaches decrease on cleared floodplains beyond a fringe of trees along the stream.

The infrequently active floodplain is the final floodplain surface to have abandoned channels. Unlike channels on previous surfaces, these are often separated from the active floodplain. Annual flooding events may affect existing channels and sloughs but not the floodplain surface which is affected by periodic flooding of larger than normal water discharges.

Abandoned floodplains and terraces have few if any abandoned channels oxbows or sloughs. These surfaces are least susceptible to flood events. Most terraces are not likely to be flooded because of their height above other floodplain surfaces.

Floodplains with numerous active and abandoned channels are close to the existing stream, only slightly elevated above the existing streams and hence, most susceptible to flooding. The trend of decreasing channels away from the stream parallels not only flood susceptibility but also a change in the type and character of vegetation. Generally, forests are deciduous with broken canopies on younger floodplain surfaces near the stream and coniferous on floodplain surfaces furthest from the stream. Studies by Viereck (1970) in interior Alaska have found a similar trend with respect to coniferous vegetation on older floodplain surfaces. Density of the forest canopy also increases away from the stream.

CONCLUSIONS

Floodplains interpreted on aerial photography were divided into five categories. Typically, the following divisions would be encountered from the existing stream channel and proceeding across the floodplain: active, partly active, infrequently active, abandoned and terraces (Fig. 30). Each floodplain category is distinguished by specific surficial conditions, including flowing and standing water, subordinate channels or sloughs (active and abandoned), vegetation type, density of the forest canopy and height above existing stream surfaces. Generally, flowing and standing water and subordinate channels and sloughs are typical in the vicinity of streams and vegetative landcover consists of deciduous forests with open canopies. Away from the primary stream-channel the number of subordinate channels and sloughs decrease, coniferous trees appear, the mixed forest develops a more closed canopy, the elevation of the floodplain surface increases and standing water is less prevalent.

The decrease of stream channels and appearance of coniferous vegetation away from the stream parallels the decrease in flood susceptibility of floodplain surfaces.

RECOMMENDATION

One purpose of this study is to describe stream corridor physiography to aid decisions relating to floodplain management. This report provides geogrpahically mapped data concerning relative flood susceptibility, geographic relationships of floodplains, surface morphology and generalized vegetative cover. Further studies which could provide additional complementary data are:

(1) Detailed analysis of vegetation including type and density of forests and understory prepared from CIR aerial photography with field verification.

(2) Tree ring analysis for dating flood frequency and the age of the floodplain.

(3) Correlate transverse ground profiles of floodplains at stream gage locations for further correlations of surface morphology with the areal extent of major historic floods.

(4) Map soils and soil moisture on floodplain surfaces.

(5) Record depth to water table where information is available.

Recommendation #1 is a routine remote sensing investigation procedure. Recommendation #2 thru #5 are detailed analysis techniques which if applied to a specific accessible study area (such as the Susitna River) would further describe the physical conditions of each floodplain surface. These physical conditions could be used to model each type of floodplain and then be extrapolated to other floodplain surfaces mapped from aerial photography.

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APPENDIX:

Comparison

Landsat Imagery vs. Aerial Photography

COMPARISON

Landsat Imagery vs. Aerial Photography

Floodplain map units in this study were compared to those mapped from 1:125,000 scale Landsat imagery on a previous study (Dean, 1980). Although the objective of the previous study involved regional surficial geology, the comparison is informative.

Floodplains interpreted on Landsat imagery are divided into three categories; fa-active, f_1-partly or infrequently active, and f_2-abandoned. Criteria used to distinguish these categories are: contrast with surrounding cover types, geometric patterns, geographic position and shadows caused by scarps.

Floodplains mapped on the aerial photography are divided into five categories; fa-active, f_1-partly active, f_2-infrequently active, f_3-abandoned and tr-terraces. Criteria used to distinguish these categories are the same as those based on Landsat interpretations plus vertical relief from the stereo coverage and density of forest canopy.

Comparing the floodplain maps indicate that there is close agreement between the boundaries of the active floodplains and the boundaries defining the extent of floodplains. The intervening floodplain surfaces between these two extremes are also similar in that those interpreted from Landsat imagery are divided into two categories, and those interpreted from the aerial photography are divided into four categories. Generally, partly active and infrequently active photographic categories are equivalent to the partly or infrequently active Landsat category of floodplains, and abandoned and terrace photographic categories are equivalent to abandoned Landsat category of floodplains (Table 19).

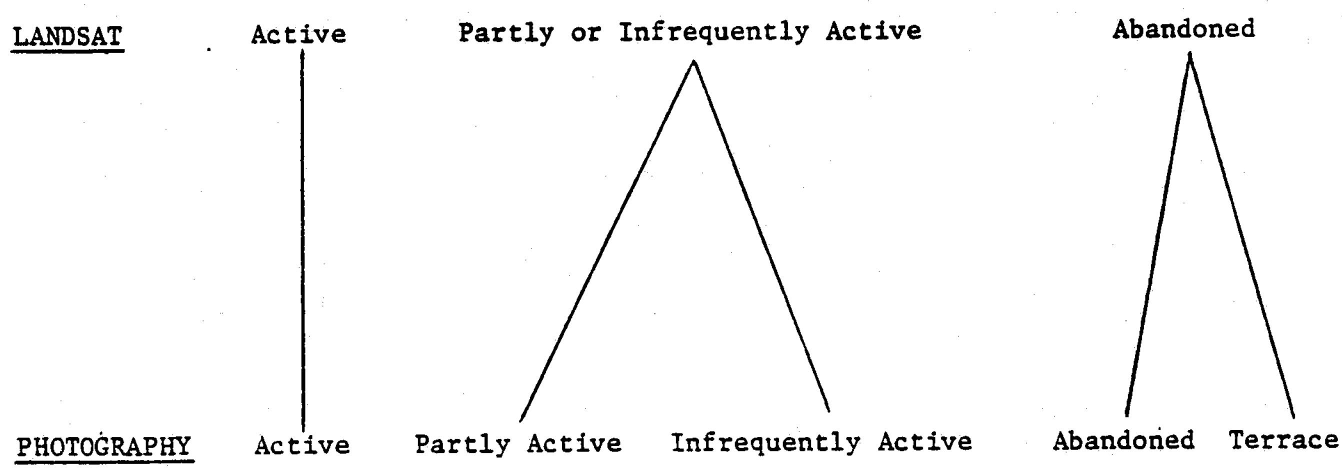

Table 19. A comparison of floodplain categories interpreted from Landsat imagery and high-altitude aerial photography.

Generally, on Landsat imagery (1:250,000 scale), a mappable floodplain is greater than 1km wide but on 1:125,000 scale imagery (the largest visually interpretable scale which can be efficiently utilized) floodplains as small as ½ km wide are mappable.* Interpretable floodplains mapped from 1:120,000 scale aerial photography are greater than 100m wide.*

*These estimates are based upon floodplain measurements along the Susitna and Kahiltna Rivers.

APPENDIX K

INTRISCA PROJECT

ACCURACY ASSESSMENT OF THE INTRISCA STUDY REGION

L. Morrissey, D. Card, M. McDonald

As part of NASA's technology transfer demonstration program and in conjunction with numerous state agencies, NASA has mapped generalized land use and land cover for a region in southcentral Alaska using digital analysis of Landsat satellite data. Accuracy assessment was performed for one area within the study region based on the Soil Conservation Service (SCS) vegetation map produced for the Willow subbasin.[1]

To estimate the accuracy of the Landsat-derived classification, a number of cluster samples randomly located throughout a representative subsection of the map were compared with SCS mapped units available for the same areas. Although accuracy is referred to throughout the paper, this assessment is only valid to the extent that the verification data base (SCS map) is an accurate representation of the land cover. Two types of comparison were made between the Landsat-derived classification and SCS mapped data sets: 1) the creation of contingency tables or confusion matrices, and 2) calculation of percentage correct for each resource class.

Due to major time and budget constraints and the availability of photo-interpreted land cover maps produced by the Soil Conservation Service (SCS), NASA decided to forego expensive field reconnaissance to collect ground data information for an accuracy assessment. Therefore, vegetation maps prepared by SCS were utilized as "ground truth" to access the accuracy of the Landsat derived classification. High altitude color infrared photography (1:65,000) was used as the primary data base, supplemented with field checks.

The SCS land cover classes were generalized to a ten acre minimum mapping unit for forest land and 160 acres for non-forest lands. Classification schemes for the SCS map and Landsat-derived classification appeared to correspond initially.

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[1] As part of the Cooperation River Basin Studies, the Soil Conservation Service (U.S. Department of Agriculture) is participating with the state of Alaska in a study of water and land resources within the Susitna River Basin.

Methodology

A random sampling cluster approach was utilized in the accuracy assessment. Cluster sampling was chosen in order to minimize the effect of single pixel location errors. Taking into account the time constraints of the project and the amount of computer processing required, other decisions related to sample size are summarized as follows:

1. Cluster sampling was used rather than single pixel sampling in order to minimize the number of center points that needed to be located.

2. A cluster size of 5 pixels by 5 pixels was chosen.

3. The number of clusters was chosen to be 60 or greater as defined by time availability.

With the aid of a computer, 62 pixels were randomly located within the study area. Using these pixels as center points, the surrounding 5 x 5 cluster samples were defined. Classified maps (50 x 50-pixel size) centered on each cluster sample were produced to overlay onto the SCS cover map. The 50 x 50-pixel size was chosen to allow the interpreter to do a "visual fit" of the lineprinter (LP) map to the SCS cover data to overcome any center point locational inaccuracies. The row and column values for each of the center points were then translated into latitude and longitude using the geometric transform information previously generated for the classified image. These were then plotted onto 1:30,000 scale (photographically enlarged) USGS 15' quads. The SCS maps were overlaid onto these maps and the center points transferred.

Due to the differences in the land cover categories of the Landsat classification and SCS land cover maps certain classes from both data sets were grouped so as to ensure equivalence of land cover class definitions. Aggregation of the SCS units to correspond to the Landsat-derived categories was of limited success: a direct correspondence was not possible; overlapping class definitions and the affect of different minimum mapping units contributed to a low correspondence between the two classification schemes. This low correspondence seriously impacts the validity of the accuracy assessment. For instance, based on primary vegetation categories, a mixed coniferous/deciduous forest does not exist in the SCS classification scheme. Therefore, primary and secondary vegetation units of combined deciduous and coniferous classes were assigned to correspond to a mixed forest class in the Landsat-derived scheme. The correspondence between SCS map units and Landsat land cover categories is summarized in Table 20.

TABLE 20

Comparison of Landsat and SCS Classification Schemes

Landsat Scheme	SCS Classification Scheme
	FOREST AND WOODLAND
	Closed Forest
*	21 = Coniferous Forest, White Spruce, Short Stands
Deciduous	22 = Deciduous Forest, Mixed Forest, Young Stands
Deciduous	24 = Deciduous Forest, Mixed Forest, Medium-Aged Stands
*	25 = Coniferous Forest, White Spruce, Tall Stands
*	26 = Deciduous Forest, Mixed Forest, Old Stands
*	27 = Cottonwood, Young Stands
*	28 = Cottonwood, Medium-Aged Stands
*	29 = Cottonwood, Old Stands
	Open Forest-Woodland
Coniferous	31 = Coniferous Forest, White Spruce, Short Stands
Deciduous	32 = Deciduous Forest, Mixed Forest, Medium-Aged Stands
*	33 = Coniferous Forest, White Spruce, Tall Stands
*	34 = Deciduous Forest, Mixed Forest, Old Stands
*	35 = Cottonwood, Medium-Aged Stands
*	36 = Cottonwood, Old Stands
	Closed Forest (Black Spruce Mountain Hemlock)
Coniferous	41 = Black Spruce, Short Stands
Coniferous	42 = Black Spruce, Tall Stands
*	45 = Mountain Hemlock, Short Stands
*	46 = Mountain Hemlock, Tall Stands
	Open Forest-Woodland (Black Spruce)
*	43 = Black Spruce, Short Stands
	NON-FORESTED
	Salt Water Wetlands
Bog	50 = Salt Grassland bog
Bog	51 = Low Shrub
*	52 = Tidal Marsh
	Tall Shrubs
Shrub & Grass	60 = Alder
Shrub & Grass	61 = Alder-Willow (streamside veg.)

(continued on next page)

TABLE 20 (continued)

	Low Shrub
Shrub Grass	62 = Willow Resin Birch
	Grassland
*	63 = Upland Grass
	Tundra
Shrub & Grass	64 = Sedge-Grass
Shrub & Grass	65 = Herbacious
*	66 = Shrub
*	67 = Mat and Cushion
	Freshwater Wetlands
Bog	68 = Sphagnum Bog
Bog	69 = Sphagnum-Shrub Bog
	Cultural Features
*	70 = Cultural Influences
	Barren
Barrens	80 = Mud Flats
Barrens	81 = Rock
	Permanent Snow and Ice
*	82 = Snowfield
*	83 = Glacier
	Water
Water	91 = Lakes greater than 40 ac.
Water	92 = Lakes at least 10 ac., but less than 40 ac.
Water	96 = Streams and Rivers at least 165 feet wide, but less than 660 feet
Water	97 = Rivers greater than 660 feet wide

* SCS land cover categories not sampled in an accuracy assessment

Using the fitted 5 x 5 cluster windows, the interpretation was done on a pixel by pixel basis within each cluster sample. The center point for each cluster sample was located on the SCS cover map and the 50 x 50-pixel LP (line printer) map was overlaid and visually fitted to obvious registration features (water and pronounced vegetation boundaries). Where registration features were absent, a note was made on the data sheet for its later checking or deletion. Once the sample was located, the corresponding dominant land cover category for each pixel was determined from the map and recorded on computer coding forms.

Statistical Analysis

The appropriate statistical analysis for cluster sampling for proportions is given in the second reference (Cochran, 1977). For a given category, the proportion correct is simply the sum over all the clusters of those pixels which matched for the category, divided by a total that depends on the kind of estimate being made.

$$P = \sum_{i=1}^{n} a_i \Big/ \sum_{i=1}^{n} m_i$$

where a_i = number pixels matched for the category (PI is the same category call as Landsat) for cluster i

m_i = total number of pixels belonging to the category in cluster i

n = number of sampled clusters

The number m_i can be the number of Landsat pixels belonging to the category in cluster i, the number of PI pixels in the cluster, or the total number of pixels in the cluster, depending on how one defines the term "probability correct." These three estimators reflect the difference between omission and commission errors for each category and overall proportion correct without regard to category. For example, if one considers the commission error to be important, one would take m_i to be the number of Landsat pixels for the given class in cluster i. In terms of probability theory, this would be called the probability correct, given the Landsat category. On the other hand, if omission error is considered to be more critical, one would take the estimate with m_i the number of PI pixels in cluster i. This would give the probability correct for the category, given the PI class. The user must decide whether over-estimating or under-estimating the number of pixels in a class is the most critical. The third estimate, in which m_i is the total

number of pixels in cluster i, gives an estimate of overall proportion correct not broken down by category. It reflects total error, both commission and omission.

For each estimate p, an approximate 95% confidence interval is given by $p \pm 2\sqrt{V(p)}$ where the variance V(p) is:

$$V(p) = \frac{1-f}{\overline{m}^2} \quad \frac{\sum a_i^2 - 2p\sum a_i m_i + p^2 \sum m_i^2}{n-1}$$

and the finite population correction f is taken to be zero, since the number of clusters, n, is small in proportion to the total number of clusters in the population. The numbers a, m_i, p, and n are defined as above, and m is the mean number of pixels per cluster for the category in question.

The data from the 62 clusters are summarized in Table 20. Since there were 62 clusters, and each cluster had 25 pixels, there should have been 1550 total pixels sampled. The reason that there are only 1042 pixels in Table 20 is that two SCS map categories had no logical correspondence to any Landsat categories, and so pixels with those categories as labels were eliminated. The overall percent correct was 67, as measured by the sum of the diagonal entries in Table 21 divided by the total number of pixels.

In order to determine how much a coarser grouping might improve classification accuracies, categories bog and grass/shrub were combined into a new category called non-forest vegetation and categories conifer, mixed forest, and deciduous were combined into a new category called forest. The results are summarized in Table 22. As shown in the table, the percent correct increased to 84%.

Tables 23 and 24 show individual category probabilities correct and associated confidence intervals for the 7 category case, and Tables 25 and 26 show them for the original 7 categories grouped into 4.

Results

The contingency table (Table 21) is useful in recognizing where and why errors occur. Certain predictable errors many not affect the usefulness of the land cover map for specific purposes. For example, the percent of water bodies correctly classified on the Landsat derived map was 73% (omission) and 98% (commission) respectively. The ten-acre minimum mapping unit used by SCS in preparation of the vegetation maps would tend to eliminate many lakes and ponds. However, the Landsat-derived map could have mapped the small

TABLE 21

Contingency Table of Computer Assigned Category versus
Actual Category as Determined by the SCS Base Map

Computer Assigned Category

SCS Category	Water	Bog	Grass/ Shrub	Conifer	Mixed Forest	Deciduous	Barren	Total
Water	53	4	4	4	2	2	4	73
Bog	0	45	5	0	2	0	0	52
Grass/Shrub	0	16	118	0	7	5	16	162
Conifer	0	0	0	14	3	0	0	17
Mixed Forest	0	52	9	54	229	104	3	451
Deciduous	0	1	6	5	15	52	0	79
Barren	1	13	11	0	0	0	183	208
Total	54	131	153	77	258	163	206	1042

Total Proportion Correct = . 67
Standard Error = .0438

TABLE 22

Contingency Table of Computer Assigned Category versus Actual Category as Determined by the SCS Base Map (Categories grouped from Table 21)

	Computer Assigned Category				
SCS Category	Water	Non-forest Vegetation	Forest	Barren	Total
Water	53	8	8	4	73
Non-forest Vegetation	0	184	31	16	231
Forest	0	68	459	3	530
Barren	1	24	0	183	208
Total	54	284	498	206	1042

Total Proportion Correct = . 84
Standard Error = .0285

TABLE 23

Probability of Correct Classification and Confidence Bounds, given Actual Category, for 7 Category Classification (1 - p is the omission error for each category)

SCS Category	p Probability Correct Classification	95% Confidence Interval
Water	.726	(.382, 1.0)
Bog	.865	(.661, 1.0)
Grass/Shrub	.728	(.439, 1.0)
Conifer	.824	*
Mixed Forest	.508	(.393, .623)
Deciduous	.658	(.364, .952)
Barren	.880	(.757, 1.0)

* Insufficient number of clusters to estimate variance

TABLE 24

Probability of Correct Classification and Confidence Bounds, Given Computer Designated Category, for 7 Category Classification (1 -p is the commission error for each category)

SCS Category	p Probability of Correct Classification	95% Confidence Interval
Water	.982	(.933, 1.0)
Bog	.344	(.004, .684)
Grass/Shrub	.771	(.585, .957)
Conifer	.182	(.045, .319)
Mixed Forest	.888	(.794, .982)
Deciduous	.319	(.025, .613)
Barren	.888	(.749, 1.0)

TABLE 25

Probability of Correct Classification and Confidence Bounds,
Given Actual Category,
for 4 Category Classification
(1 - p is the omission error for each category)

SCS Category	p Probability of Correct Classification	95% Confidence Interval
Water	.726	(.382, 1.0)
Non-Forest Vegetation	.796	(.594, .998)
Forest	.866	(.817, .915)
Barren	.880	(.757, 1.0)

TABLE 26

Probability of Correct Classification and Confidence Bounds, Given Computer Designated Category, for 4 Category Classification (1 - p is the commission error for each category)

SCS Category	p Probability of Correct Classification	95% Confidence Interval
Water	.982	(.933, 1.0)
Non-Forest Vegetation	.648	(.457, .839)
Forest	.922	(.847, .997)
Barren	.888	(.749, 1.0)

ponds and lakes correctly, yet showed a low correspondence with the SCS map; hence the high omission errors. Therefore, it is helpful for the user to know not only how accurate the map is, but also what kinds of error occurred and why.

Ideally, the SCS and Landsat-derived classification schemes should have categories that have a high correspondence. This, unfortunately, was not the case. For instance, the SCS woodland category is "land with 10 - 50 percent of the area having tree crown cover or formerly having 10 - 50 percent cover. In contrast, the classification scheme for the Landsat analysis defined a woodland as having at least 30% crown cover (due to the limitations of the satellite sensors). Therefore, an area located near treeline, with perhaps 10% tree cover and 90% grasses and shrubs would be classified as a woodland on the SCS map and as a shrub and grassland on the Landsat-derived map. As a result, many omission and commission errors attributed to the Landsat map may in fact actually reflect a low correspondence to SCS land cover categories.

Examination of the contingency table highlights those categories that are most in error because of the overlapping definition of the cover categories. For example; of the SCS defined coniferous sample points (Table 23), most (82%) were correctly identified on the Landsat map. Those sample points which were not correctly identified as conifer were assigned to the Mixed Forest category, implying that the SCS confier class may have encompassed some deciduous trees. Other errors due to differing category definitions include confusion between bog and grass/shrub categories. Of those actual bog classes, 86% were correctly identified (Table 23) on the Landsat map. Those sample units in error were identified as grass and shrub on the Landsat map. Considering the vegetative composition of a typical bog, with a high proportion of grasses and shrubs, it is understandable that this type of confusion would occur: that the spectral reflectance of these two classes would be similar. Another source of error is related to the data bases (CIR photography and satellite imagery used) in preparation of each map. Again based on spectral reflectance, grass and shrubs will be spectrally identical whether they occur above the treeline (tundra), within a tidal marsh, or as the primary successional community on a timber cut. The satellite characterizes the reflectance of vegetation based on the major vegetative components within each community. Hence, the level of detail achieved on the SCS maps is not always compatible with satellite-derived resource information.

Evaluation of classification accuracy necessitates sampling each of the cover classes (Rohde, 1978). Based on the ran-

dom sampling within the area encompassed by the SCS data base, only 21 of the 41 SCS categories were sampled (Table 20). In addition, the areal coverage of the SCS map in the Willow subbasin was not representative of all environments found within the (Landsat) study region. That is, of the 13 million acres within the Susitna basin, the Willow subbasin represents approximately 1 million acres. Therefore, sampling of all categories would not be possible unless additional data bases were available. In addition, of the twenty-two Landsat classes, only ten were sampled (Table 27).

Utilization of the SCS map for determining the accuracy of the Landsat-derived map assumes that the SCS base map is 100% correct. As a result, any error that may exist within the SCS base map will decrease the percentage correct of the Landsat-derived resource classes. A review of SCS computer printouts listing information derived from ground visits reveal a number of inconsistent identifications of land cover categories between ground visit class and class assigned during actual photo-interpretation of photography. Therefore, there is a possibility that some error may have occurred during preparation of the SCS maps. These errors which were the result of inaccurate photo interpretation will detrimentally affect the accuracy of the Landsat-derived map.

Two sources of error to be found in the interpretation portion of the accuracy assessment are: 1) locational errors and 2) errors in interpreters' judgment. Locational difficulties occur whenever map-to-map registration is required. The image calibration file used to locate the latitude and longitude of each cluster sample center point has a root mean square error of 3 pixels. In addition, location of cluster samples is made more difficult because of the ten acre minimum mapping used in the SCS map. As a result, land features used in the registration procedures, smaller than 10 acres, have been eliminated. Since both the USGS quads and SCS cover maps were not precision enlarged there was a registration/scale error of approximately ¼ inch from top to bottom between the maps. The registration difficulties caused by this were minimized, wherever possible, by doing a visual fit of the SCS map to the USGS quad using lakes as mutual reference points. Once the calibration points were transferred onto the SCS maps the 50 x 50 windows were "visually fitted" to their most probable location. In many cases (those containing a nearby water body) a fit could be made within one pixel, thus alleviating most of the previous locational errors; in other instances, the locational error could be ± 2 pixels, a result of homogeneous terrain or cover. It can be seen that wherever a "visual fit" was done, the judgment of the

TABLE 27

Aggregation of Landsat Categories
to Correspond to SCS Map Units

Landsat Categories	Aggregated Categories
Sedimented/Shallow water	Water
Deep water	Water
Shrub bog	Bog
Black spruce bog	Bog
Grass	Grass and Shrub
Shrub	Grass and Shrub
Coniferous Forest	Coniferous Forest
Mixed Forest	Mixed Forest
Deciduous Forest	Deciduous Forest
Barrens	Barrens
Alpine tundra	*
Glaciers	*
Snow	*
Cloud	*
Shadow	*
Commercial/Industrial	*
Transportation Facilities	*
High density residential	*
Low density residential	*
Central business district	*
Commercial	*
Agricultural Fields	*

* Landsat categories not sampled in accuracy assessment

interpreter affects the validity of the location. This judgment error also comes into play in the decisions concerning the dominance of a land cover within a pixel. For this project, the dominant land over type for each pixel was the land cover type that represented the greater portion of the ground cover within the pixel. As one might imagine, small locational differences might drastically change the decisions of the interpreter with regards to dominance.

Conclusions

An estimate of accuracy of the Landsat derived land cover map was based on cluster samples distributed throughout an area encompassed within the SCS map (Willow subbasin). A contingency table was generated for each resource class giving the probability of correct classification (commission and omission), with the appropriate confidence interval. A coarser grouping of land cover classes was found to increase overall accuracy.

The overall percentage correct does not necessarily reflect the accuracy of the-Landsat derived map, but may represent a poor correspondence between the SCS and Landsat classification schemes. The principal sources of classification error are due to:

1) Overlapping land cover category definitions,
2) Minimum mapping unit differences,
3) Possible photo-interpretation errors,
4) Locational and interpretation errors,
5) Spectral confusion between land cover categories, and
6) Incorrect identification of Landsat land cover categories

A rigorous statistical analysis of accuracy would have required ground checks utilizing only one classification scheme. Due to budget limitations, ground visits were not possible. Therefore, this paper has documented the correlation of SCS units to Landsat land cover categories, rather than provide a statement of map accuracy.

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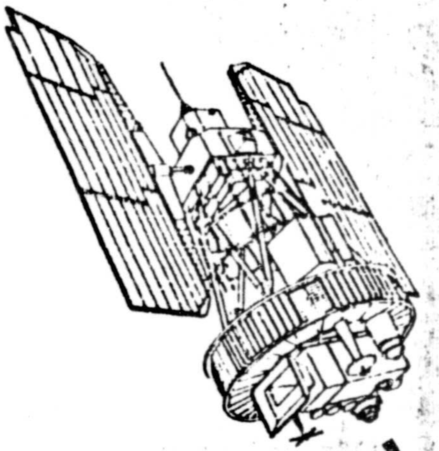
APPENDIX L

GEOGRAPHIC INFORMATION SYSTEM INTEGRATION

Jack Dangermond

Demonstration of Landsat Data Integration Into an Automated Geographic Data Base for the Hillside Area, Anchorage, Alaska



ORIGINAL PAGE IS
OF POOR QUALITY

Municipality of Anchorage
Planning Department
Pouch 6-650
Anchorage, Alaska

NASA
National Aeronautics and Space Administration
Ames Research Center
Moffett Field, California

Demonstration of Landsat Data Integration into an Automated Geographic Data Base for the Hillside Area, Anchorage, Alaska

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Preface

Every organization, private or public, and every citizen in a community at one time or another needs geographic information. Most often, this information is obtained from maps. Is it the maps that are important? No, it is the information on them that we need. So why do we have so many maps? Because it is much easier for the human mind to understand a picture than it is for any other type of communication. Maps present pictures of geography; they present information and it is the information that we use to make decisions.

The information must be acquired, classified, analyzed, maintained, managed, and presented to us, the users, in a manner and format that best fits our needs. Manual mapping and records systems meet some of our needs, but they are totally inflexible when one presentation format is used to try to satisfy everyone's needs. Secondly, users frequently need information from several maps at once, to show correlation, new spatial patterns, constraints and opportunities for some project. Only a computer can manipulate such vast quantities of information and present it in a new format and present new information maps in a rapid, cost efficient manner.

This demonstration project has utilized computer mapping techniques, used satellite data, interpreted aerial photographs, and utilized collateral data sources as inputs to the computer to test the effectiveness of applying an automated geographic information system to an on-site problem in Anchorage.

The Municipality of Anchorage wishes to thank NASA for the opportunity to participate in one of their technology application transfer projects. The use of Landsat data integrated with a geographic information system has addressed a real planning issue and resulted in providing maps to assist in both future planning efforts in the test site as well as provided a framework for management decision making.

C-3

Introduction

One of the NASA demonstration sub-projects conducted with the Municipality was a project in which an automated geographic information system was developed to serve as a test for both the process of integrating classified Landsat data into a comprehensive environmental data base and the process of using automated information in land capability/suitability analysis and environmental planning. The test site used for this demonstration was the Hillside area of Anchorage, lying approximately 7 miles southwest of the downtown area, and extending over an area of some 25 square miles. (Figure 32.)

Purpose

The test site was particularly selected so that the results of the demonstration could be compared with a parallel effort being conducted on the Hillside: a waste water management plan.

The purpose of the NASA demonstration was to compare the output products with those of the consultant, specifically the septic tank suitability maps. This effort was part of a NASA technology transfer program in which high technology developments are made available and transferred to state and local governments. The intent was to demonstrate that use of a computer system could effectively produce quality map information in a rapid and cost effective manner.

Methodology Overview

The land capability/suitability concept uses the approach that the physical characteristics of a particular area may be examined to determine what the land is best suited for, by overlaying (compositing) thematic maps containing the relevant physical factors and interpretations.

An automated geographic information system was developed and applied toward the evaluation of land capability/suitability in the area. It had a spatial resolution of 2½ acres, areal units smaller in extent not being mapped as discrete units. The environmental resource data (from the Anchorage Coastal Resource Atlas) was inventoried, mapped, automated and analyzed for purposes of the study. All data was mapped in a form closely representing their natural configuration. Areal phenomena such as soil, surficial geology, vegetation and landforms were mapped as polygons. Linear phenomena such as roads and streams were mapped as lines. Small scale phenomena such as excavation sites were mapped as points. Compatible data variables were composited on the same map at the same time as rescaled boundaries were being recitified and redrawn. This compositing of compatible data onto one map is called integrated terrain unit mapping (Fig. 33). The methodology permits eight data variables to be composited onto one map. In total, four manually drafted sheets, termed map manuscripts, were prepared. These and the data encompassed within them are outlined in Table 28.

All of the manuscripts, except the integrated terrain unit maps, were manualy delineated and subsequently automated at a scale of 1:63,360. The integrated terrain unit maps were delineated and automated at a larger scale of 1:37,000 in order to provide optimal representation of the more detailed data variables composited on them. These manuscripts were created through a process which involved spatial integration as well as compositing. In the preparation of these maps, interrelated data variables were cross compared as well as checked against the imagery and basemap, and where appropriate, boundary discrepancies reconciled. This process resulted in the enhancement of the resolution, accuracy, and consistency of the original data. The integrated manuscript maps, like all others, were comprised of a series of consecutively numbered units delineated on a mylar sheet registered to a basemap. These were accompanied by code sheets which expressed the attributes of each area by means of numeric codes. In addition, a coded interpretive matrix was developed and automated as a means of expanding the soil data plane in the system (Figures 34 and 35).

The mapped data were automated by a process of X, Y coordinate digitizing. The automation procedures provided for the accurate capture of the natural form of the mapped data. The computerized data files, comprised of polygons, line segments, and points, were used to create a number of plotter drawn maps of the test site, as well as to create a parallel set of data files in a grid format. A uniform 1½ acre (80 meter) grid was laid atop each of the automated X, Y coordinate data files for the test site, and the data values were transferred into and recorded by individual grid cell. Classified Landsat data was similarly formulated and merged into the grid multi-variable file. This additional data plane, land cover, was created through the supervised classification of raw Landsat digital values for 80 meter pixels and the spatial trans-

FIGURE 32

HILLSIDE TEST SITE

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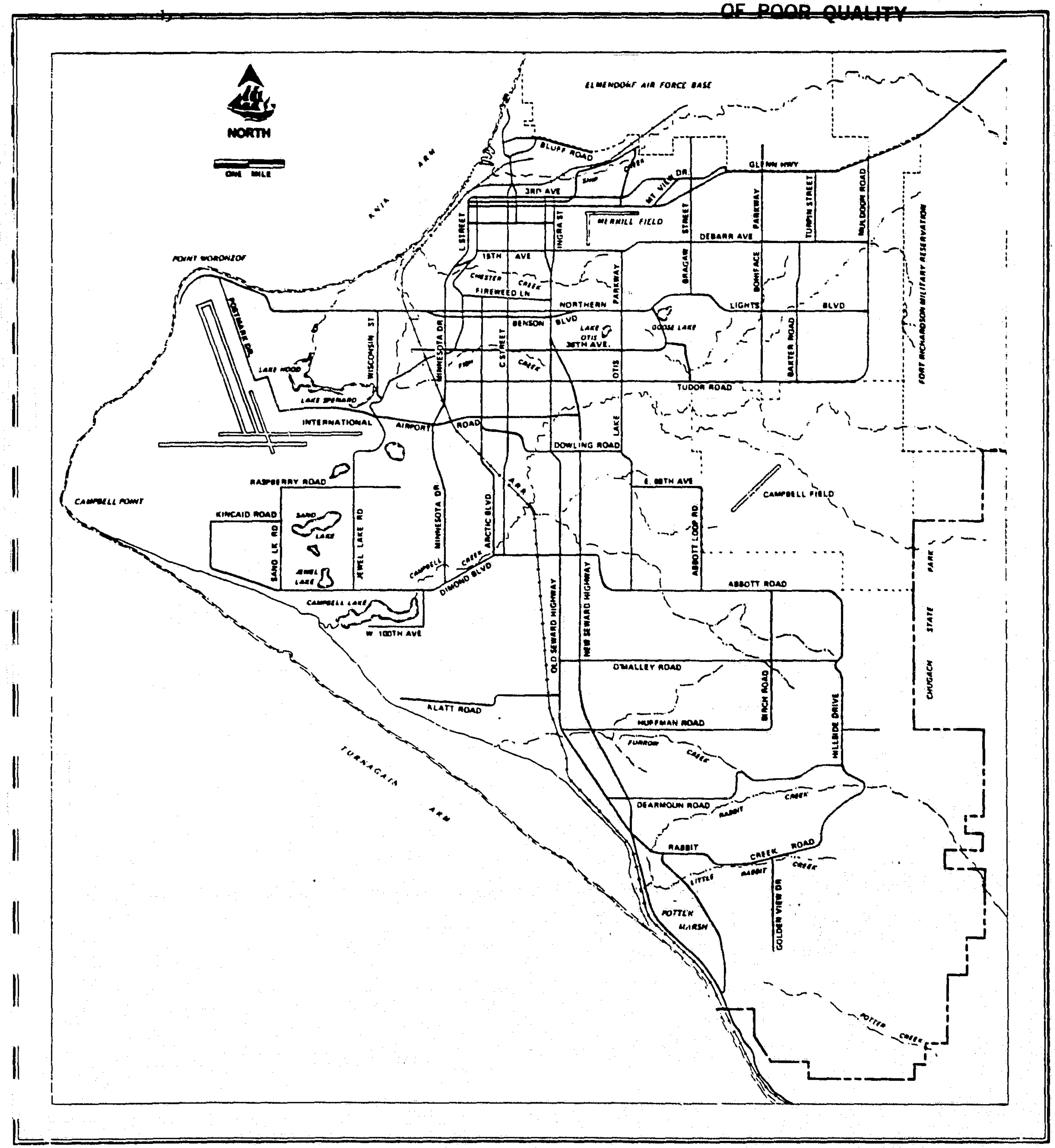


formation and registration of these data on IDIMS (Interactive Digital Image Manipulation System). Initially compiled as grid single-variable files, these data were plotted and checked for spatial accuracy and registration before being merged into the grid multi-variable file of other data.

The automated data bank was then used to produce a number of maps illustrating basic environmental conditions. Subsequently, they were used to do the following: assess environmental opportunities and constriants; evaluate land capability and land suitability; and compare automated classified Landsat land cover information with photointerpreted vegetation units. With respect to the latter, a simple discrete statistical procedure included correlation tables which were applied for the comparison of the data. The following maps were generated for the Hillside test site:

Polygon Plot Maps @ 1:25,000 scale

- Land Use and Roads
- Watershed and Streams

Grid Electrostatic Maps @ 1:25,000 scale

- Vegetation (photointerpreted)
- Land Cover (Landsat)
- Geologic Hazards
- Slope
- Specific Soil Slope
- Soil Drainage
- Soil Limitations for Dwellings
- Soil Limitations for Septic Tank
- Land Capability for Large Lot Residential Development

TABLE 28: Map Manuscript Composition

Map Manuscript #1	**Integrated Terrain Unit Map**
	Slope
	Landform Type
	General Geology
	Economic Geology
	Soil Type
	Land Use
	Vegetation Type
Map Manuscript #2	**Surface Hydrology Map**
	Stream Courses
	Watershed
Map Manuscript #3	**Points and Linear Features Map**
	Natural Lines
	Escarpments
	Fault Lines
	Cultural Lines and Points
	Road
	Extractive Sites
Map Manuscript #4	**Land Status Map**
	Townships
	Ownership

MAP MANUSCRIPT #1
INTEGRATED TERRAIN UNITS

FIGURE 33

SLOPE
Slope Gradient, Column 1
1 = 0- 3%
2 = 3- 7%
3 = 7-12%
4 = 12-20%

LANDFORM
Physiographic Division, Column 2
1 = Mountain
2 = Hill
3 = Plateau
4 = Valley
Landform Type, Column 3, 4, 5
Glacial
110 = Moraine
111 = End Moraine
112 = Lateral Moraine
120 = Till
Fluvio Glacial
210 = Outwash
Aeolian
310 = Dune
Fluvial
530 = Flood Plain
Water Body
840 = River
831 = Lake
910 = Glacier

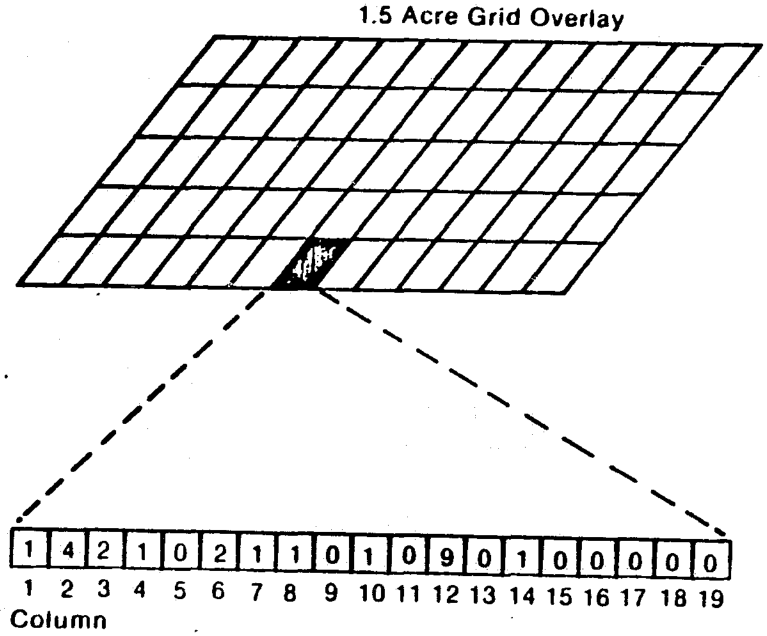
GENERAL GEOLOGY
Surficial Geology, Column 6
1 = No Surficial Deposits
2 = Surficial Deposits
3 = Water Body
Bedrock Geology, Column 7
1 = Tertiary, Undifferentiated
2 = Tertiary Intrusive
Economic Geology, Column 8
1 = Surficial deposits of gravel, sand
2 = Potential deposits of copper, etc.
9 = Water
0 = No Mineral deposits
Geologic Hazards I, Column 9, 10
01 = Flood Zone
02 = Outburst Flood Zone
03 = Landslide Zone
04 = Avalanche chute
Geologic Hazards II, Column 11
1. Liquification, Slumps
2. No Geologic Hazard

SOILS, Column 12, 13, 14
901 = Caswell Silt Loam, 3-7% slopes

LAND USE, Column 22-25
Residential
210 = Low Density
220 = Medium Density

HABITAT, Column 15-21

VEGETATION, Column 26-33



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GEOGRAPHIC OVERLAY AND GRID CODING METHODOLOGY

FIGURE 34

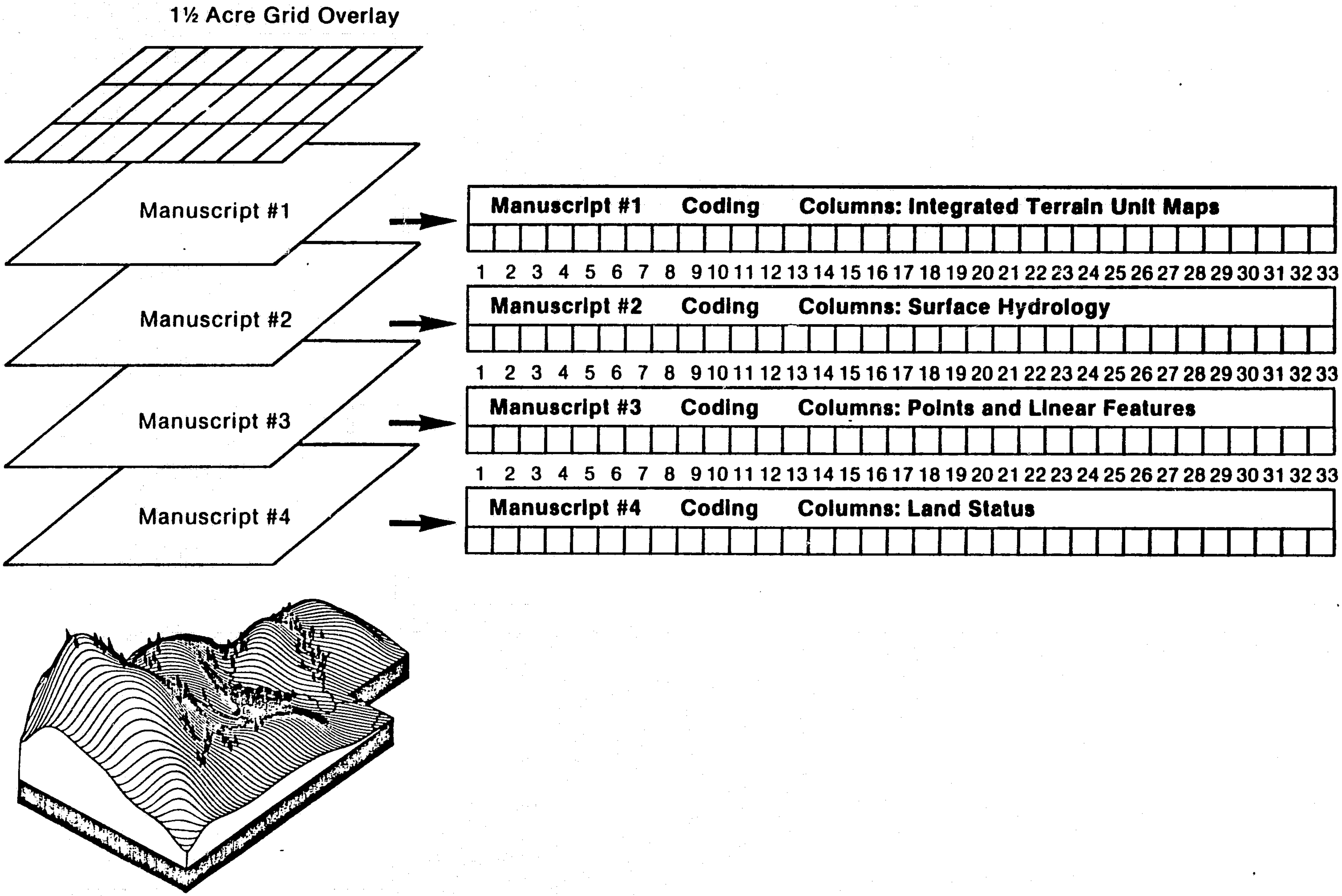
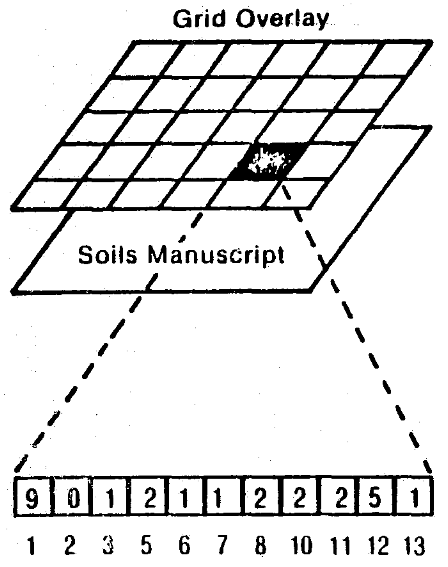


FIGURE 35

SOIL EXPANSION CODES

Variable	Matrix Column	Legend
Soil Type	1-3	
Limitations		
Septic Tank Absorption Fields	5	1
Shallow Excavations	6	1
Dwellings Without Basements	7	1
Dwellings With Basements	8	1
Small Commercial Buildings	10	1
Local Roads and Streets	11	1
Drainage	12	2
Specific Slope	13	3



SOIL EXPANSION LEGENDS

Legend	1		
	1	Slight	(Sl)
	2	Moderate	(M)
	3	Severe	(Sr)
	0	Water	
Legend	2		
	1	Excessively Drained	(E)
	2	Somewhat Excessively Drained	(SE)
	3	Well Drained	(W)
	4	Moderately Well Drained	(M)
	5	Somewhat Poorly Drained	(SP)
	6	Poorly Drained	(P)
	7	Very Poorly Drained	(VP)
	0	Water	
Legend	3		
	1	Nearly Level — 0-3%	(A)
	2	Undulating — 3-7%	(B)
	3	Rolling — 7-12%	(C)
	4	Hilly — 12-20%	(D)
	5	Moderately Steep — 20-30%	(E)
	6	Steep — 30-45%	(F)
	7	Very Steep — 45%	(G)

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Technical Task Description

Each of the fourteen tasks comprising the steps to conduct this project are described and illustrated in this section. Fig.36 illustrates this process.

Task 1

The first task was designed to identify the data types and levels which were required for the successful completion of the project. This effort is conducted first among the series of tasks in order to develop an early, clear and effective understanding of the project needs, scope and purpose.

Task 2

This task involved the acquisition of existing base maps, aerial photography and imagery and collateral reports and maps.

Task 3

This task was designed to familiarize the study team with the actual patterning of environmental phenomena in the study area and thereby establishing a sound basis for focused investigation, data classification, interpretation, and analysis.

Task 4

The purpose of this task was to provide an environmental description of the study area which highlighted those problems, constraints and opportunities which were considered as major issues in carrying out the project. This information also served as a basis for development of the data classification systems for each data attribute that best met the purpose of the study.

Task 5

An accurate and consistently scaled base map is required as a basis for any natural resource mapping effort. This task involved the process of compiling and formatting of the base map and images which in turn provided the foundation for the accurate location and delineation of all mapped phenomena. The base map provided the framework for rectifying boundaries of phenomena initially delineated on the basis of conventional aerial photography and collateral map data.

Task 6

This task involved the manual photo interpretation of both high altitude color infrared photography and conventional natural color aerial photography. Photo interpretation techniques were used to interpret and delineate broad geologic, pedologic, biotic and anthropic patterns, environmental conditions and land use patterns. Aerial photography was also employed in the update of the base map and in the delineation of actual boundaries for geographic phenomena described but not mapped in collateral sources.

Task 7

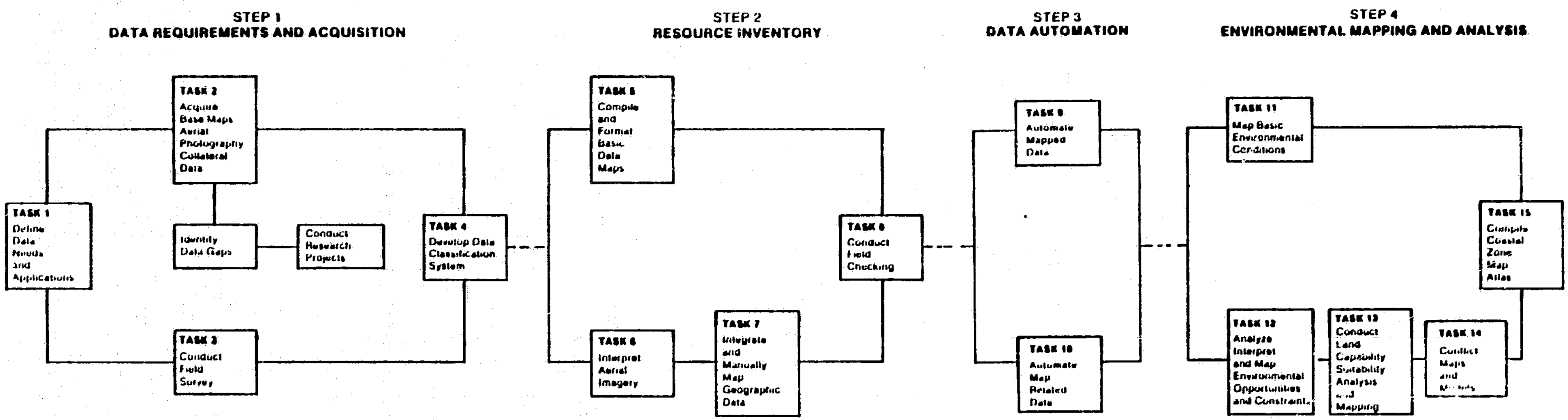
Task seven encompassed the integration and mapping of geographic data derived from the processes of field survey, data acquisition, and photo interpretation. Data are normally resolved, integrated and mapped in relation to the general patterns evident on the aerial photography and are registered to known features and coordinates on the topographic base maps. Fundamental geographic units, termed terrain units served as the basis for the integration, resolution and delineation of a wide range of geographic attributes. Terrain units and their boundaries are normally defined by a set of basic and homogeneous physiographic, geologic, pedologic, and vegetative conditions. Data integrations and, in particular, terrain unit mapping, provides for a higher level of spatial resolution and accuracy than is otherwise inherent in the overlay of diverse collateral data. Essentially, the process involves the resolution of all data to natural patterns which are evident or interpretable on the aerial imagery and on the topographic base map. The terrain unit maps, like other maps displaying geographic data, are manually drafted on stable mylar and are coded for automation. The diverse data encompassed within the terrain unit manuscript were structured in such a manner that they could be easily segregated and mapped as independent phenomena after the process of data automation was complete. Integration provides for a high level of resolution for a high level of efficiency in the process of data automation. For purposes of this project a spatial resolution of 2½ acres was used.

Task 8

This task was designed to verify the accuracy of the data which have been interpreted, integrated and mapped and to make any desirable or necessary changes to the manuscript maps before they were automated.

FIGURE 36

COASTAL MANAGEMENT RESOURCE INVENTORY AND ENVIRONMENTAL ANALYSIS FLOW CHART



BASIC DATA MAPS (TASK 5)

Administrative Boundaries
Land Ownership
Stream Network
Water Bodies/Watershed
Land Use
Surficial Geology
Soils
Slope
Vegetation
Landform

ENVIRONMENTAL OPPORTUNITIES AND CONSTRAINTS MAPS (TASK 10)

Mineral Resources
Seismic Hazards
Avalanche Zones
High Wind Zones
Flooding
Visual Quality
Wildlife Habitats
Wetlands
Archaeological
Forest Resources
Coastal Erosion
Slope Stability
Foundation Conditions

LAND CAPABILITY/SUITABILITY MAPS (TASK 11)

Urban Waterfront
Residential
Commercial
Industrial
Rural
Recreation

Task 9

Once the data were verified the next task involved the automation of the manuscript maps which were manually prepared. Mapped data were automated by a means which preserves and records their spatial integrity. A digitizer was used to automate the X, Y coordinates of all mapped points, lines, and polygons. Digitizing is a procedure used to record thematic data, such as soils, vegetation, and geology, in a digital format for subsequent processing by a computer. The digitizing process, which centers upon the recording of X, Y coordinates and numeric codes for phenomena spatially expressed as polygons, lines, and points, results in the accurate and efficient automation of geographic phenomena. Geographic data are thus retrievable for display and analysis in their natural form. In addition, data are transformed into a grid format for alternate and complementary display and analysis. A uniform grid, 1½ acre cells, was overlayed atop the data in the point, line and polygon files and all of the computerized data are automatically transferred into the grid structure. A grid cell size smaller than the minimum polygon resolution was used. In this project polygons were mapped at a minimum resolution of 2½ acres whereas the grid cell captured the geographic data in 1½ acre cells. This provides for the preservation of the scale and quality of the point and line data and the capture of the general form and boundaries of the polygons. Once completed, the grid files join the existing point, line and polygon files in comprising the fundamental geographic data bank for computer mapping and analysis. Such a composite data bank can be recalled or manipulated in either the polygon or grid form.

Task 10

This task was conducted concurrently with that of map automation. It involved the entry of codes for the geographic phenomena which have been mapped. These codes identify the nature and attributes of the data items. For example, a long code series is typically automated for each of the integrated terrain unit maps. These codes identify such basic characteristics of each of the terrain unit polygons as landform, geology, soils and vegetation. In many cases the basic code sets which detail the interpretive characteristics of the mapped data can be expanded. For example, a code can identify a soils type or association. An expanded code permits the characteristics of a particular soil type to be interpreted in terms of its engineering and physical characteristics. They usually encompass such attributes as porosity, permeability, and stability. Expansion code sets are also employed for such things as the automation of statistical data for mapped political, administrative and statistical reporting units. Thus, mapped units such as census tracts and traffic analysis zones are identified by codes which in turn reference an expanded code set elaborating economic, social, and demographic data. The process of code automation, when carried out in a hierarchical manner, provides for the entry of a vast array of data into the map structure created through the process of point, line and polygon digitizing.

Task 11

This task involved the graphic display of the geographic data which have been interpreted, mapped, and automated. It is designed to produce a series of maps which illustrate the location and distribution of baseline environmental conditions. These maps, which show the distribution of all of the basic environmental phenomena which bear on the description and analysis of the study site, encompass both maps and statistical tabulations. The statistical tabulations indicate the areal extent of all mapped data in relative and absolute numbers. They provide a statistical summary for such mapped phenomena as land use types, soil types, and vegetation types within the study area. The maps are created in two map formats. One or more of the mapped variables can be created in a plotter mode on translucent mylar in a point, line, and polygon format. The second format is a grid map produced on an electrostatic printer/plotter which displays the data in a gray tone, with gray tone shades and patterns being used to delineate geographic phenomena. It is important to note that the output scale of both the polygon and the grid maps can be varied. These base maps serve many purposes. In conjunction with an accompanying explanatory text, they provide a comprehensive description and illustration of baseline environmental conditions. In addition, they provide an illustration of the content and reference for the opportunity/constraint maps and land capability/suitability maps which were subsequently produced.

Task 12

Once the baseline maps were completed this task established the interpretive environmental framework for the general evaluation of land capability/suitability within the study boundaries. The task involved the analysis and interpretation of basic environmental data. Theoretical models were developed and applied to

the automated data base. These models provided for the legible and systematic evaluation of environmental conditions which may serve as opportunities or constraints in relation to the location and conduct of human activities. Individual models were designed to rank areas within the study area according to such phenomena as geologic/seismic hazard, flood hazard, erosion potential, ecological sensitivity, slope stability, visual quality and extractive mineral (sand, gravel) potential. In general the modeling process is iterative, with each model undergoing several iterations before being finalized. The application of each final model to the automated data base resulted in the creation of both a data file which was subsequently drawn upon in the process of land capability/suitability analysis and of a map which displayed the direct results of the interpretive process. The opportunity /constraint models developed under this task were designed to expand the environmental information which was mapped and to broaden the environmental data base used in the evaluation of specific land capability/suitability in the study area. These models provided basic and practical interpretations of environmental patterns and processes. A variety of model types were employed in the process of evaluating environmental opportunities and constraints. Typically, the models are additive ones. Relative numerical values are assigned to individual variables. Overlay and addition of these in the computer results in development of differing numerical values for different portions or areas within the study boundaries.

Task 13

This task was conducted in relation to three phenomena: basic geographic data; interpreted environmental opportunities and constraints; and select types of planned human activity. In this instance, the planning for septic tanks and/or sewer systems on the Hillside in Anchorage was the intended goal. This effort culminates the long process of data selection, classification, mapping, analysis, and interpretation. **It represents the basic step in the application of environmental considerations in the process of land use planning.**

Theoretical models were designed to provide for the legible and systematic ranking of areas within the study area in relation to select classes of human activity. In this case, land capability-/suitability analysis was carried out in relation to the following: soil limitations for dwellings with and without basements; soil limitations for septic tanks; and capability for accessed large lot residential development. The development of land capability-/suitability models requires a thorough understanding of the environmental requirements and demands of each activity type. Each land capability/suitability model was developed by means of an interactive process in which both environmental and planning expertise was required. The application of each final model to the automated data base resulted in the creation of a series of maps displaying four levels of land capability/suitability for the particular activity referenced above: high, moderate, low; and unsuitable. Together with the area calculations for each of the classifications, these maps serve as the fundamental input in the determination of land supply in the processes of land allocation and planning. Collectively these maps provide a coherent and consistent environmental direction and framework for the formulation of all of the elements of a comprehensive plan. Mathematical modeling represents the fundamental process whereby automated environmental data can be used in the determination, areal definition, and designation of areas of differing land capability/suitability in any given study area. The process may be conceptualized as the establishment of a set of mathematical scales and relations among geographic phenomena and between these phenomena and some projected elements or process. Because of the complexities of land use processes, it is not normally practical to construct a single model to describe a host of land use capability and suitability interpretations. The questions of land use are sufficiently complex to warrant the development of a series of independent models that can stand alone or be used in combination during the planning process. This has been the case in this study.
Each model consists of three fundamental elements:

- definition of a specific objective,
- specification and inclusion of data variables that are pertinent and significant, and
- enumeration of data relationships and weightings which objectively express some natural and cultural process, or which are responsive to a legitimate set of subjectively derived criteria or policies.

Task 14

This final task represents preparation and presentation of the maps and final report, as set forth in this report.

Analysis and Discussion

One of the primary purposes in selecting the Hillside as the study area was to compare the output products of this computer application with the results obtained by the consultant who used manual techniques. The only data not available for this demonstration project was well-log data which was available for the consultants study. Comparisons of the two data sets must therefore recognize this data omission.

Three models were developed for the study area. The first two, soil limitations for dwellings/buildings with and without basements, and soil limitations for septic tanks were put through additional iterations to produce a composite model for land capability for accessed large lot residential development. Considerations, specific data classes, incidence values and model summation rules are illustrated in Figure 37.

Model 1 - Limitations for Septic Tanks
A septic tank absorption field is commonly comprised of a subsurface tile system used to distribute effluent from a septic tank into the natural soil. Criteria used for rating soils for use as absorption fields are based on limitations of the soil to uniformly absorb effluent. The most important factors are soil permeability, location of the water table, flooding hazard, slope gradient, soil wetness, permafrost, and geological data since soil surveys account for only the top five feet of soil. Permeability of the geologic formations was a main consideration. The physical and chemical properties as well as the engineering properties of the various soil associations were also incorporated into the model.

As a result of the fourteen task process, plus use of expansion codes for soil it was possible to model and code each soil type as to the degree of limitation for septic tank absorption fields.

Model 2 - Limitations for Dwelling With and Without Basements
The emphasis in rating soils for building sites is based on the properties that affect foundation support, but also considered were slope, susceptibility to flooding, seasonal wetness, permafrost, depth to bedrock, physical characteristics of soil types, soil erosion/drainage characteristics, slope gradient and surficial geology. Properties influencing foundation support are those affecting bearing capacity, settlement load, and cost of excavation and construction. Sliding hazard interpretations were conducted using the geology data.

Model 3 - Capability for Accessed Large Lot Residential Development
This model is shown as an example in Fig. 38, and represents a composite of models one and two.

Statistical Tabulations

After the models were applied against the automated data base and the capability/suitability maps were produced it was possible for the computer to generate area calculations for each classification in each model as well as total area calculations for several of the baseline maps.

These are illustrated in Table 29.

Landsat Integration

Vegetation/land cover for the study area was conducted in two modes. First, color infrared aerial photographs were interpreted and land cover/vegetation maps were manually produced. The Landsat data was classified on a computer system and a generalized land cover classification scheme developed. Since Landsat data is in digital form and its smallest picture element is 1.12 acres, it was easily reformatted to fit a 1.5 acre grid. The statistical comparisons between the two data sets were in the form of contingency tables that indicate the number of cells of correlation, the percentage of the row, percentage of the column, and the percentage of the table. The aggregation decisions made were of two types for the comparison. First, an unbiased aggregation was done by examining the code descriptions for the land use/vegetation data set. The second aggregation was accomplished by examining the contingency table of the ungrouped codes and assigning an aggregated code based upon the highest correlation. These tables are shown in Tables 30, 31, and 32.

TABLE 29

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MODEL OUTLINE
LAND CAPABILITY FOR ACCESSED LARGE LOT RESIDENTIAL DEVELOPMENT

Consideration	Specific Data Class	Value (Incidence)	Value (Proximity)
Landform Type	Glacial		
	Moraine	H	
	Till	H	
	Drumlin		
	Drumlin/Drumloid	H	
	Rock Drumlin	NR	
	Fluvioglacial		
	Outwash	H	
	Abandoned Outwash Channel	H	
	Remnant Subglacial Stream Valley	H	
	Kame Complex	H	
	Esker	H	
	Crevasse Filling	H	
	Side Glacial Drainage Channel	H	
	Flute	H	
	Aeolian		
	Dune	L	
	Littoral		
	Longshore Bar	L	
	Beach	L	
	Barrier Spit	L	
	Delta	L	
	Tidal Flat	U	
	Coastal Plain	NR	
	Fluvial		
	Active Channel	U	
	River Bar	U	
	Floodplain		
	Active	U	
	Abandoned	NR	
	Alluvial Plain	H	
	Alluvial Fan/Cone	H	
	Lacustrine Deposit	H	
	Mass Wasting		
	Colluvium	U	
	Talus	U	
	Landslide Deposit	U	
	Rock Glacier	U	
	Mine Tailings	U	
	Tectonic Uplift		
	Upland Valley	H	
	Mountain Sideslope	NR	
	Mountain Ridgetop	NR	
	Waterbody	U	
	Ice and Snow	U	
Slope Gradient	Average Slope Gradient		
	0 - 3%	H	
	3 - 7%	H	
	7 - 12S	H	
	12 - 20%	M	
	20 - 30%	L	
	30 - 45%	L	
	GT45%	U	
	Specific Slope Phase		
	0 - 3%	H	
	3 - 7%	H	
	7 - 12%	H	
	12 - 20%	M	
	20 - 30%	M	
	30 - 45%	L	
	GT45%	U	
Geologic Hazard	Primary Potential Flood Zone	U	
	Secondary Potential Flood Zone	NR	
	Outburst Flood Zone	U	
	Catastrophic Wave Zone	U	
	Landslide Zone	U	
	Varying Particle Size	NR	
	Unstable Ground	NR	
	Avalanche Track	U	
Soil Characteristics	Septic Tank Limitations		
	Slight	H	
	Moderate	M	
	Severe	L	
	Limitations for Dwellings With Basements		
	Slight	H	
	Moderate	M	
	Severe	M	
	Limitations for Dwellings Without Basements		
	Slight	H	
	Moderate	M	
	Severe	L	
	Limitations for Local Roads and Streets		
	Slight	H	
	Moderate	H	
	Severe	M	
	Drainage		
	Excessively Drained	M	
	Somewhat Excessively Drained	H	
	Well Drained	H	
	Moderately Well Drained	M	
	Somewhat Poorly Drained	L	
	Poorly Drained	U	
	Very Poorly Drained	U	
Water Availability	Potential Well Yield Area		
	Area 1	L	
	Area 2 or 3	H	

MODEL SUMMATION RULES

Ratings are scanned within each general category encompassing more than one factor and the most severely constraining rating is used to provide the overall rating for the category. In effect, each general consideration - landform, soils, water availability, etc., - has a single rating when summation begins. The following summation procedures are used:

High Capability	GE1H and Not EQ M L or U
Moderate Capability	EQ1 or 2M and Not EQ L or U
Low Capability	GT2M or EQ1 or 2L and Not EQ U
Incapable	GT2L or GE 1U

Where GE = Greater than or equal to
H = High (1H) one high (2H) 2 high
EQ = Equal to
M = Moderate (2M) 2 moderates
L = Low
U = Unsuitable
GT = Greater than

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TABLE 30
Statistical Tabulations

Soil Limitations for Septic Tanks, Landsat/AGIS Intergration Demonstration
Municipality of Anchorage, Hillside Area

CLASS	SYMBOL	TOTAL AREAS (Hectares)	PERCENTAGE
Slight	C	1,278.72	19.71
Moderate	M	1,251.20	19.29
Severe	T	3,952.00	60.93
Water	Blank	4.48	0.07

Soil Limitations for Dwellings with/without Basements
Landsat/AGIS Ingration Demonstration
Municipality of Anchorage, Hillside Area

CLASS	SYMBOL	TOTAL AREAS (Hectares)	PERCENTAGE
Slight	C	1,442.56	22.24
Moderate	M	1,324.16	20.41
Severe	T	3,715.20	57.28
Water	Black	4.48	0.07

General Slope, Landsat/AGIS Integration Demonstration
Municipality of Anchorage, Hillside Area

CLASS	SYMBOL	TOTAL AREAS (Hectares)	PERCENTAGE
0-3	C	2,4189.56	37.29
3-7	D	1,975.56	30.45
7-12	K	630.40	9.72
12-20	M	962.56	14.84
20-30	P	336.64	5.19
30-45	T	163.20	2.52

TABLE 30, Continued

Vegetation Map, Landsat/AGIS Integration Demonstration
Municipality of Anchorage, Hillside Area

CLASS	SYMBOL	TOTAL AREAS (Hectares)	PERCENTAGE
Mudflat	Z	307.84	4.75
Saltwater Wetland	X	252.80	3.90
Sphagnum-Shrub Bog	T	279.68	4.31
Willow - Resin Birch	S	11.52	0.18
Alder	P	583.68	9.00
Tall White Spruce	O	573.44	8.84
Short White Spruce	M	610.56	9.41
Medium-Aged Mixed Forest	K	1,063.04	16.39
Young Mixed Forest	F	228.48	3.52
Upland Grass	D	64.64	1.00
Developed	A	2,506.24	38.64
Water	Blank	4.48	0.07

Geologic Hazards, Landsat/AGIS Integration Demonstration
Municipality of Anchorage, Hillside Area

CLASS	SYMBOL	TOTAL AREAS (Hectares)	PERCENTAGE
No Hazard	D	6,386.56	98.46
Potential Flood Zone	S	66.56	1.03
Landslide Zone	X	28.80	0.44
Water	Blank	4.48	0.07

Soil Drainage, Landsat/AGIS Integration Demonstration
Municipality of Anchorage, Hillside Area

CLASS	SYMBOL	TOTAL AREA (Hectares)	PERCENTAGE
Excessive	A	36.48	0.56
Somewhate Excessive	D	78.72	1.21
Well	K	4,389.76	67.68
Moderately Well	M	113.92	1.76
Somewhate Poor	P	3.20	0.05
Poor	T	905.60	13.96
Very Poor	Z	954.24	14.71
Water	Blank	4.48	0.07

TABLE 31

ROWS: VEGETATION COLUMNS: LANDSAT UNGROUPED HILLSIDE

	1	2	3	4	5	6	7	8	9	10	11	12	13	18	19	25	26	ALL
2	1	81	400	25	0	275	223	155	102	151	19	88	2	365	243	0	182	2312
	04	3.50	17.30	1.08	--	11.89	9.65	6.70	4.41	6.53	82	3.81	09	15.79	10.51	--	7.87	100.00
	.1	22.75	29.41	41.67	--	46.85	13.63	11.43	18.72	25.46	13.10	27.24	15.38	22.73	35.84	--	33.96	22.81
	01	80	3.95	25	--	2.71	2.20	1.53	1.01	1.49	19	87	02	3.60	2.40	--	1.80	22.81
3	2	77	231	3	0	13	88	19	5	103	71	32	8	418	126	3	1	1200
	17	6.42	19.25	25	--	1.08	7.33	1.58	42	8.58	5.92	2.67	67	34.83	10.50	25	08	100.00
	63	21.63	16.99	5.00	--	2.21	5.38	1.40	92	17.37	48.97	9.91	61.54	26.03	16.58	33.33	19	11.84
	02	76	2.28	03	--	13	87	19	05	1.02	70	32	08	4.12	1.24	03	01	11.84
4	1	6	0	0	1	0	2	0	1	2	2	0	0	28	1	0	0	44
	2.27	13.64	--	--	2.27	--	4.55	--	2.27	4.55	4.55	--	--	63.64	2.27	--	--	100.00
	31	1.69	--	--	7.69	--	12	--	18	34	1.38	--	--	1.74	15	--	--	43
	01	06	--	--	01	--	02	--	01	02	02	--	--	28	01	--	--	43
5	0	1	31	0	0	1	10	1	2	6	3	0	0	25	6	0	0	86
	--	1.16	36.05	--	--	1.16	11.63	1.16	2.33	6.98	3.49	--	--	29.07	6.98	--	--	100.00
	--	28	2.28	--	--	17	61	07	37	1.01	2.07	--	--	1.56	88	--	--	85
	--	01	31	--	--	01	10	01	02	06	03	--	--	25	06	--	--	85
7	1	9	6	0	0	1	11	4	1	13	3	2	0	61	17	0	0	129
	78	6.98	4.65	--	--	78	8.53	3.10	78	10.08	2.33	1.55	--	47.29	13.18	--	--	100.00
	31	2.53	44	--	--	17	67	29	18	2.19	2.07	62	--	3.80	2.51	--	--	1.27
	01	09	06	--	--	01	11	04	01	13	03	02	--	60	17	--	--	1.27
8	0	0	6	0	0	3	4	1	0	45	0	0	0	26	14	0	0	99
	--	--	6.06	--	--	3.03	4.04	1.01	--	45.45	--	--	--	26.26	14.14	--	--	100.00
	--	--	44	--	--	51	24	07	--	7.59	--	--	--	1.62	2.06	--	--	98
	--	--	06	--	--	03	04	01	--	44	--	--	--	26	14	--	--	98
11	5	7	1	0	0	1	0	0	0	5	3	0	0	15	3	0	0	40
	12.50	17.50	2.50	--	--	2.50	--	--	--	12.50	7.50	--	--	37.50	7.50	--	--	100.00
	1.57	1.97	07	--	--	17	--	--	--	84	2.07	--	--	93	44	--	--	39
	05	07	01	--	--	01	--	--	--	05	03	--	--	15	03	--	--	39
12	0	0	0	0	0	0	0	0	0	0	0	0	0	5	1	0	0	6
	--	--	--	--	--	--	--	--	--	--	--	--	--	83.33	16.67	--	--	100.00
	--	--	--	--	--	--	--	--	--	--	--	--	--	31	15	--	--	06
	--	--	--	--	--	--	--	--	--	--	--	--	--	05	01	--	--	06
21	0	29	134	4	0	64	257	167	43	18	18	16	0	119	52	0	33	954
	--	3.04	14.05	42	--	6.71	26.94	17.51	4.51	1.89	1.89	1.68	--	12.47	5.45	--	3.46	100.00
	--	8.15	9.85	6.67	--	10.90	15.71	12.32	7.89	3.04	12.41	4.95	--	7.41	7.67	--	6.16	9.41
	--	29	1.32	04	--	63	2.54	1.65	42	18	18	16	--	1.17	51	--	33	9.41
22	0	6	52	1	6	31	20	38	19	36	1	8	0	87	36	0	16	357
	--	1.68	14.57	28	1.68	8.68	5.60	10.64	5.32	10.08	28	2.24	--	24.37	10.08	--	4.48	200.00
	--	1.69	3.82	1.67	46.15	5.28	1.22	2.80	3.49	6.07	69	2.48	--	5.42	5.31	--	2.99	3.52
	--	06	51	01	06	31	20	37	19	36	01	08	--	86	36	--	16	3.52
24	0	41	292	4	1	59	576	272	43	58	12	50	3	154	90	0	6	1661
	--	2.47	17.58	24	06	3.55	34.68	16.38	2.59	3.49	72	3.01	18	9.27	5.42	--	36	100.00
	--	11.52	21.47	6.67	7.69	10.05	35.21	20.06	7.89	9.78	8.28	15.48	23.08	9.59	13.27	--	1.12	16.39
	--	40	2.88	04	01	58	5.68	2.68	42	57	12	49	03	1.52	89	--	06	16.39
25	0	29	37	2	0	23	246	299	35	26	8	53	0	114	16	0	8	896
	--	3.24	4.13	22	--	2.57	27.46	33.37	3.91	2.90	89	5.92	--	12.72	1.79	--	89	100.00
	--	8.15	2.72	3.33	--	3.92	15.04	22.05	6.42	4.38	5.52	16.41	--	7.10	2.36	--	1.49	8.84
	--	29	37	02	--	23	2.43	2.95	35	26	08	52	--	1.12	16	--	08	8.84
50	0	3	10	1	4	10	2	0	9	6	0	2	0	15	9	0	30	101
	--	2.97	9.90	99	3.96	9.90	1.98	--	8.91	5.94	--	1.98	--	14.85	8.91	--	29.70	100.00
	--	84	74	1.67	30.77	1.70	12	--	1.65	1.01	--	62	--	93	1.33	--	5.60	1.00
	--	03	10	01	04	10	02	--	09	06	--	02	--	15	09	--	30	1.00
51	0	11	5	1	1	25	28	1	10	16	0	6	0	23	2	0	0	129
	--	8.53	3.88	78	78	19.38	21.71	78	7.75	12.40	--	4.65	--	17.83	1.55	--	--	100.00
	--	3.09	37	1.67	7.69	4.26	1.71	07	1.83	2.70	--	1.86	--	1.43	29	--	--	1.22
	--	11	05	01	01	25	28	01	10	16	--	06	--	23	02	--	--	1.22
52	16	18	5	0	0	11	0	0	3	8	0	15	0	55	23	2	9	169
	9.70	10.91	3.03	--	--	6.67	--	--	1.82	4.85	--	9.09	--	33.33	13.94	1.21	5.45	100.00
	5.-2	5.06	37	--	--	1.87	--	--	55	1.35	--	4.64	--	3.42	3.39	22.22	1.68	1.69
	16	18	05	--	--	11	--	--	03	08	--	15	--	54	23	02	09	1.69
60	0	2	28	9	0	39	55	270	227	6	4	7	0	23	16	0	226	910
	--	22	3.07	99	--	4.28	6.03	29.61	24.89	66	44	77	--	2.52	1.75	--	24.78	100.00
	--	56	2.06	15.00	--	6.84	3.36	19.91	41.65	1.01	2.76	2.17	--	1.43	2.36	--	42.16	9.00
	--	02	28	09	--	38	54	2.66	2.24	06	04	07	--	23	16	--	2.23	9.00
62	0	0	1	0	0	1	8	2	3	1	0	0	0	2	0	0	0	10
	--	--	5.56	--	--	5.56	44.44	11.11	16.67	5.56	--	--	--	11.11	--	--	--	100.00
	--	--	07	--	--	17	49	15	55	17	--	--	--	12	--	--	--	10
	--	--	01	--	--	01	08	02	03	01	--	--	--	02	--	--	--	10
63	0	0	20	3	0	8	12	8	9	4	0	0	0	25	6	0	6	100
	--	--	19.80	2.97	--	7.92	11.88	7.92	8.91	3.96	--	--	--	24.75	5.94	--	5.94	100.00
	--	--	1.47	5.00	--	1.36	73	59	1.65	67	--	--	--	1.56	88	--	1.12	1.00
	--	--	20	03	--	08	12	08	09	04	--	--	--	25	06	--	06	1.00
69	0	2	100	7	0	22	91	116	33	9	1	1	0	24	13	0	18	430
	--	46	22.88	1.60	--	5.03	20.82	26.54	7.55	2.06	23	23	--	5.49	2.97	--	4.12	100.00
	--	56	7.35	11.67	--	3.75	5.56	8.55	6.06	1.52	69	31	--	1.49	1.92	--	3.36	4.30
	--	02	99	07	--	22	90	1.14	33	09	01	01	--	24	13	--	18	4.30
80	293	34	0	0	0	0	0	0	0	80	0	43	0	22	4	4	1	48
	60.91	7.07	--	--	--	--	--	--	--	16.63	--	8.94	--	4.57	83	83	21	100.00
	91.85	9.55	--	--	--	--	--	--	--	13.49	--	13.31	--	1.37	59	44.44	19	4.70
	2.89	34	--	--	--	--	--	--	--	79	--	42	--	22	04	04	01	4.70
92	0	0	1	0	0	0	3	3	0	0	0	0	0	0	0	0	0	
	--	--	14.29	--	--	--	42.86	42.86	--	--	--	--	--	--	--	--	--	100.00
	--	--	07	--	--	--	18	22	--	--	--	--	--	--	--	--	--	00
	--	--	01	--	--	--	03	03	--	--	--	--	--	--	--	--	--	00
ALL	319	356	1360	60	13	587	1636	1356	545	593	145	323	13	1606	678	9	536	1013
	3.15	3.51	13.42	59	13	5.79	16.14	13.38	5.38	5.85	1.43	3.19	13	15.85	6.69	09	5.29	100.00
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	3.15	3.51	13.42	59	13	5.79	16.14	13.38	5.38	5.85	1.43	3.19	13	15.85	6.69	09	5.29	100.00

TABLE 32

ROWS: LANDSAT COLUMNS: VEGETATION AGGREGATION #1 HILLSIDE

	1	2	3	4	5	6	7	8	9	10	11	ALL
1	0	5	3	2	0	0	16	0	0	0	293	319
	--	1.57	.94	.63	--	--	5.02	--	--	--	91.85	100.00
	--	12.50	.09	.55	--	--	4.05	--	--	--	60.91	3.15
	--	.05	.03	.02	--	--	.16	--	--	--	2.89	3.15
2	0	7	158	16	47	58	32	2	0	2	34	356
	--	1.97	44.38	4.49	13,20	16.29	8.99	.56	--	.56	9.55	100.00
	--	17.50	4.50	4.40	2.33	3.14	8.10	.22	--	.46	7.07	3.51
	--	.07	1.56	.16	.46	.57	.32	.02	--	.02	.34	3.51
3	1	1	631	43	344	171	20	29	20	100	0	1360
	.07	.07	46.40	3.16	25.29	12.57	1.47	2.13	1.47	7.35	--	100.00
	14.29	2.50	17.97	11.81	17.05	9.24	5.06	3.12	19.80	22.88	--	13.42
	.01	.01	6.23	.42	3.39	1.69	.20	.29	.20	.99	--	13.42
4	0	0	28	0	5	6	2	9	3	7	0	60
	--	--	46.67	--	8.33	10.00	3.33	15.00	5.00	11.67	--	100.00
	--	--	.80	--	.25	.32	.51	.97	2.97	1.60	--	.59
	--	--	.28	--	.05	.06	.02	.09	.03	.07	--	.59
5	0	0	0	1	7	0	5	0	0	0	0	13
	--	--	--	7.69	53.85	--	38.46	--	--	--	--	100.00
	--	--	--	.27	.35	--	1.27	--	--	--	--	.13
	--	--	--	.01	.07	--	.05	--	--	--	--	.13
6	0	1	288	5	90	87	46	40	8	22	0	587
	--	.17	49.06	.85	15.33	14.82	7.84	6.81	1.36	3.75	--	100.00
	--	2.50	8.20	1.37	4.46	4.70	11.65	4.30	7.92	5.03	--	5.79
	--	.01	2.84	.05	.89	.86	.45	.39	.08	.22	--	5.79
7	3	0	311	27	596	503	30	63	12	91	0	1636
	.18	--	19.01	1.65	36.43	30.75	1.83	3.85	.73	5.56	--	100.00
	42.86	--	8.86	7.42	29.53	27.19	7.59	6.77	11.88	20.82	--	16.14
	.03	--	3.07	.27	5.88	4.96	.30	.62	.12	.90	--	16.14
8	3	0	174	6	310	466	1	272	8	116	0	1356
	.22	--	12.83	.44	22.86	34.37	.07	20.06	.59	8.55	--	100.00
	42.86	--	4.95	1.65	15.36	25.9	.25	29.25	7.92	26.54	--	13.38
	.03	--	1.72	.06	3.06	4.60	.01	2.68	.08	1.14	--	13.38
9	0	0	107	4	62	78	22	230	9	33	0	545
	--	--	19.63	.73	11.38	14.31	4.04	42.20	1.65	6.06	--	100.00
	--	--	3.05	1.10	3.07	4.22	5.57	24.73	8.91	7.55	--	5.38
	--	--	1.06	.04	.61	.77	.22	2.27	.09	.33	--	5.38
10	0	5	254	66	94	44	30	7	4	9	80	593
	--	.84	42.83	11.13	15.85	7.42	5.06	1.18	.67	1.52	13.49	100.00
	--	12.50	7.23	18.13	4.66	2.38	7.59	.75	3.96	2.06	16.63	5.85
	--	.05	2.51	.65	.93	.43	.30	.07	.04	.09	.79	5.85
11	0	3	90	8	13	26	0	4	0	1	0	145
	--	2.07	62.07	5.52	8.97	17.93	--	2.76	--	.69	--	100.00
	--	7.50	2.56	2.20	.64	1.41	--	.43	--	.23	--	1.43
	--	.03	.89	.08	.13	.26	--	.04	--	.01	--	1.43
12	0	0	120	2	58	69	23	7	0	1	43	323
	--	--	37.15	.62	17.96	21.36	7.12	2.17	--	.31	13.31	100.00
	--	--	3.42	.55	2.87	3.73	5.82	.75	--	.23	8.94	3.19
	--	--	1.18	.02	.57	.68	.23	.07	--	.01	.42	3.19
13	0	0	10	0	3	0	0	0	0	0	0	13
	--	--	76.92	--	23.08	--	--	--	--	--	--	100.00
	--	--	.28	--	.15	--	--	--	--	--	--	.13
	--	--	.10	--	.03	--	--	--	--	--	--	.13
18	0	15	783	145	241	233	93	25	25	24	22	1606
	--	.93	48.75	9.03	15.01	14.51	5.79	1.56	1.56	1.49	1.37	100.00
	--	37.50	22.29	39.84	11.94	12.59	23.54	2.69	24.75	5.49	4.57	15.85
	--	.15	7.73	1.43	2.38	2.30	.92	.25	.25	.24	.22	15.85
19	0	3	369	39	126	68	34	16	6	13	4	678
	--	.44	54.42	5.75	18.58	10.03	5.01	2.36	.88	1.92	.59	100.00
	--	7.50	10.51	10.71	6.24	3.68	8.61	1.72	5.94	2.97	.83	6.69
	--	.03	3.64	.38	1.24	.67	.34	.16	.06	.13	.04	6.69
25	0	0	3	0	0	0	2	0	0	0	4	9
	--	--	33.33	--	--	--	22.22	--	--	--	44.44	100.00
	--	--	.09	--	--	--	.51	--	--	--	.83	.09
	--	--	.03	--	--	--	.02	--	--	--	.04	.09
26	0	0	183	0	22	41	39	226	6	18	1	536
	--	--	34.14	--	4.10	7.65	7.28	42.16	1.12	3.36	.19	100.00
	--	--	5.21	--	1.09	2.22	9.87	24.30	5.94	4.12	.21	5.29
	--	--	1.81	--	.22	.40	.38	2.23	.06	.18	.01	5.29
ALL	7	40	3512	364	2018	1850	395	930	101	437	481	10135
	.07	.39	34.65	3.59	19.91	18.25	3.90	9.18	1.00	4.31	4.75	100.00
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	.07	.39	34.65	3.59	19.01	18.25	3.90	9.18	1.00	4.31	4.75	100.00

TABLE 33

ROWS: LANDSAT COLUMNS: VEGETATION AGGREGATION #2 HILLSIDE

	1	2	3	4	5	6	7	8	9	ALL
1	0	5	3	2	0	0	16	0	293	319
	--	1.57	.94	.63	--	--	5.02	--	91.85	100.00
	--	12.50	.09	.55	--	--	4.05	--	60.91	3.15
	--	.05	.03	.02	--	--	.16	--	2.89	3.15
2	0	7	158	16	8	99	32	2	34	356
	--	1.97	44.38	4.49	2.25	27.81	8.99	.56	9.55	100.00
	--	17.50	4.50	4.40	.58	2.28	8.10	.46	7.07	3.51
	--	.07	1.56	.16	.08	.98	.32	.02	.34	3.51
3	1	1	631	43	101	463	20	100	0	1360
	.07	.07	46.40	3.16	7.43	34.04	1.47	7.35	--	100.00
	14.29	2.50	17.97	11.81	7.28	13.19	5.06	22.88	--	13.42
	.01	.01	6.23	.42	1.00	4.57	.20	.99	--	13.42
4	0	0	28	0	13	10	2	7	0	60
	--	--	46.67	--	21.67	16.67	3.33	11.67	--	100.00
	--	--	.80	--	.94	.28	.51	1.60	--	.59
	--	--	.28	--	.13	.10	.02	.07	--	.59
5	0	0	0	1	6	1	5	0	0	13
	--	--	--	7.69	46.15	7.69	38.46	--	--	100.00
	--	--	--	.27	.43	.03	1.27	--	--	.13
	--	--	--	.01	.06	.01	.05	--	--	.13
6	0	1	288	5	79	146	46	22	0	587
	--	.17	49.06	.85	13.46	24.87	7.84	3.75	--	100.00
	--	2.50	8.20	1.37	5.69	4.16	11.65	5.03	--	5.79
	--	.01	2.84	.05	.78	1.44	.45	.22	--	5.79
7	3	0	311	27	95	1079	30	91	0	1636
	.18	--	19.01	1.65	5.81	65.95	1.83	5.56	--	100.00
	42.86	--	8.86	7.42	6.84	30.73	7.59	20.82	--	16.14
	.03	--	3.07	.27	.94	10.65	.30	.90	--	16.14
8	3	0	174	6	318	738	1	116	0	1356
	.22	--	12.83	.44	23.45	54.42	.07	8.55	--	100.00
	42.86	--	4.95	1.65	22.91	21.02	.25	26.54	--	13.38
	.03	--	1.72	.06	3.14	7.28	.01	1.14	--	13.38
9	0	0	107	4	258	121	22	33	0	545
	--	--	19.63	.73	47.34	22.20	4.04	6.06	--	100.00
	--	--	3.05	1.10	18.59	3.45	5.57	7.55	--	5.38
	--	--	1.06	.04	2.55	1.19	.22	.33	--	5.38
10	0	5	254	66	47	102	30	9	80	593
	--	.84	42.83	11.13	7.93	17.20	5.06	1.52	13.49	100.00
	--	12.50	7.23	18.13	3.39	2.91	7.59	2.06	16.63	5.85
	--	.05	2.51	.65	.46	1.01	.30	.09	.79	5.85
11	0	3	90	8	5	38	0	1	0	145
	--	2.07	62.07	5.52	3.45	26.21	--	.69	--	100.00
	--	7.50	2.56	2.20	.36	1.08	--	.23	--	1.43
	--	.03	.89	.08	.05	.37	--	.01	--	1.43
12	0	0	120	2	15	119	23	1	43	323
	--	--	37.15	.62	4.64	36.84	7.12	.31	13.31	100.00
	--	--	3.42	.55	1.08	3.39	5.82	.23	8.94	3.19
	--	--	1.18	.02	.15	1.17	.23	.01	.42	3.19
13	0	0	10	0	0	3	0	0	0	13
	--	--	76.92	--	--	23.08	--	--	--	100.00
	--	--	.28	--	--	.09	--	--	--	.13
	--	--	.10	--	--	.03	--	--	--	.13
18	0	15	783	145	137	387	93	24	22	1606
	--	.93	48.75	9.03	8.53	24.10	5.79	1.49	1.37	100.00
	--	37.50	22.29	39.84	9.87	11.02	23.54	5.49	4.57	15.85
	--	.15	7.73	1.43	1.35	3.82	.92	.24	.22	15.85
19	0	3	369	39	58	158	34	13	4	678
	--	.44	54.42	5.75	8.55	23.30	5.01	1.92	.59	100.00
	--	7.50	10.51	10.71	4.18	4.50	8.61	2.97	.83	6.69
	--	.03	3.64	.38	.57	1.56	.34	.13	.04	6.69
25	0	0	3	0	0	0	2	0	4	9
	--	--	33.33	--	--	--	22.22	--	44.44	100.00
	--	--	.09	--	--	--	.51	--	.83	.09
	--	--	.03	--	--	--	.02	--	.04	.09
26	0	0	183	0	248	47	39	18	1	536
	--	--	34.14	--	46.27	8.77	7.28	3.36	.19	100.00
	--	--	5.21	--	17.87	1.34	9.87	4.12	.21	5.29
	--	--	1.81	--	2.45	.46	.38	.18	.01	5.29
ALL	7	40	3512	364	1388	3511	395	437	481	10135
	.07	.39	34.65	3.59	13.70	34.64	3.90	4.31	4.75	100.00
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	.07	.39	34.65	3.59	13.70	34.64	3.90	4.31	4.75	100.00

Conclusions

The methodologies employed in this demonstration project have resulted in the enclosed maps. These maps are of sufficient detail and accuracy to be very useful in local planning efforts. It is evident that the data compositing techniques (ITUM Integrated Terrain Unit Mapping concept and Landsat integration) used for this study can effectively portray the interactions of a variety of relevant physical factors. The resulting maps allow the community to make improved land management decisions that may result in optimum use of its land resources. The correlation between the products of the demonstration project and the final map produced by the consultant are within 5 percent of each other. The discrepancy is attributed to not having available the well-log data for the demonstration project. In terms of cost, the demonstration project cost less than $10,000 versus a cost of $53,000 for the consultants study.

While there is a continuing need to update and obtain new data about the physical, biological and cultural features of the Municipality, it is readily apparent that state-of-the-art tools and techniques can be applied to investigate and solve municipal problems in a cost effective manner. It is recommended that serious consideration be given to employing such tools and techniques in conducting the day-to-day planning activities of the Planning Department. The result would be reduced cost of operation, increased efficiency and speed, and better utilization of existing staff in responding to community needs.

The Role of Computer Technology in Planning Applications

Growth and urban development, coupled with concern over the social, economic, cultural and environmental conditions of Anchorage are placing demands on the planning and administrative abilities of local government officials. The demand for local government services is increasing, yet inflation and increasing fiscal constraints combine to erode the purchasing power of local government budgets. The problems and challenges encountered in effective management and planning in Anchorage are becoming increasingly difficult and complex.

Faced with these situations, management and Municipal officials are beginning to ask complex questions, the answers to which will help them formulate policies that best serve the overall aims of the Municipality. Many of these questions require data from multiple functional and geographic areas within the government structure. One concern that has social, economic and environmental impact is land use planning.

Land use issues are, today, generating a great deal of concern, controversy, and publicity.

Anchorage, like many cities, is facing an immense problem in both understanding and guiding the development of its land, water, and human resources. The need for the ability to anticipate and evaluate the consequences of alternative courses of action is required. Decision making requires explicit and detailed analysis of the ramifications of decisions upon them. The primary objective is to place the Municipality in a position to have the ability to geographically handle large amounts of data from diverse sources, to access this data and produce relevant information for planning and management decisions by using a computer information system. Information systems intended for land use are, by definition, geographically based because most of the data held in the inventory refers to specific places where observations or measurements have been made. The design of planning information systems logically proceeds from analytical studies of the need for a system and its objectives to the determination of the data and processing needed to accomplish those objectives. The decision to automate an information system rests on the economic advantages of the cost of the computer system and its support personnel versus the cost of a manual system and the additional factors of quantities of data to be manipulated, response time, and repetitive processing.

In a broad sense, the Planning Department often functions as a data inventory and information system in which manual operations play a predominant role. The quantity of data that can be manually handled is, however, limited by the size of the work force, which depends on budget limitations, so that for large and rapidly growing planning jurisdictions, the problems of manually handling large quantities of data, evaluating alternatives, as well as monitoring and regulating land use becomes an impossible job.

Take for example, the data base currently being developed for the Planning Department. All of the data available for the Eagle

River area and the Anchorage Bowl are being digitized and formatted to the grid concept previously discussed. As a result there will be some 400 data variables possible for every 1½ acre grid cell. There is no way this amount of information could ever be manually overlayed, composited or analyzed.

As land use planners we describe, explain, and evaluate alternative future patterns of land use for parcel or larger areas and recommend a particular choice or scheme of priorities for development. The planning process results in parcels or larger areas being committed or recommended for a particular future use, according to some set of priorities and an evaluation of the area for development. The key, however, is in knowing who is doing what to the land, what the impacts and trends are, and why. To accomplish these tasks, the planner requires the tools with which to investigate, make decisions and evaluate alternatives. Much of the present planning effort is devoted to collection and analysis; however, the emphasis should be on the interpretation of information, evaluation and monitoring. Utilization of a planning information system would provide the information crucial to current and future planning decisions facing the Municipality it would permit such uses as modeling planning alternatives, allowing rapid identification and development of policy guidelines by which to evaluate development plans, as well as permit monitoring and evaluating development to name a few. Use of an automated information system is a desirable objective because computer methods are not only faster and less expensive per unit of production than non-automated methods, but automation provides the capacity to analyze large quantities of data at a speed and level not possible before as well as reduce the amount of error inherent in manual manipulation.

With the recent and rapid growth of Anchorage and the surrounding communities the Municipality must be in a position to describe the present and future situation to provide the factual bases for development of a workable comprehensive development plan, and to regulate, monitor, and evaluate performance in accord with the plan. Use of an information system for planning can be the means of bringing together information not only to answer questions, but quite often even to determine what the questions are.

Anchorage today needs to evaluate its community in terms of the following types of questions:

- Is there sufficient amount of land available to accommodate the need for future development?
- How will the development of land presently zoned for development impact public services?
- Are land use development patterns changing over time because of the policies designed to control that development?
- Do decision makers, administrators and planning department staff have all the existing data and access to it upon which to develop plans, make recommendations and decisions?

Requirements of the Physical Planning Division

The Land Use Division has responsibility for all comprehensive plan development, coastal zone management planning and management, utility corridor analysis, hazard studies, parks and trails planning, school site selection, historic preservation, wetland, water and air quality management and planning. Development of plans for these subject areas requires extensive research, data acquisition and mapping. Mapping is manually done and results in static products; the data cannot be readily compared or combined with other data sets. For each project a new set of maps must be manually produced and area statistics manually calculated. Presently, it is very difficult to review effectively our data against specific requirements of various federal and state agency regulations in a comprehensive manner. Data are frequently received at various scales and formats which require the expenditure of dollars and manhours to reformat the data to a uniform map base.

Land use suitability analysis is a complex and detailed process requiring comparison and mapping of as many as twenty data sets against each other and then manually combining the data to produce new information.

Land use is a constantly changing variable and, as such, considerable time is spent updating and remapping land use changes each year.

Utilization of a computer mapping system would eliminate the need for manually preparing maps, reduce man hours in map preparation, allow for instant manipulation of data sets to provide new maps at any desired scale. Once a map is digitized, it is electronically captured and can be recalled, displayed, combined with other data, and then plotted automatically. The result of such a system will allow for greater and more efficient utilization of staff, allow for greater output of work per man hour, and reduce the present budget requirements for mapping needs. The computer mapping program addresses the decision-makers' problem of relating information from a communication base, consisting of mapping data and attribute data, to current decisions in an effective way. Procedures and techniques are required which allow the decision maker to model complex relationships between and among activities, resources, environmental conditions, and to determine rapidly the impact of alternative policy decisions on those relationships.

Recommendation

Recent technological advances in the computer field have taken place that now permit complex geographic data bases to be run on mini and micro computer systems. The Planning Department currently has a professional services contract with Environmental Systems Research Institute (ESRI) to develop an environmental geographic data base system. This demonstration project also utilized ESRI as a contractor to NASA, and illustrates the types of geographic data in the system currently being developed by ESRI as well as examples of analysis capabilities. A recent advance has now permitted this type of data base to be run on a micro computer, e.g. an Apple computer system. This system consists of the following components:

one Apple computer
two hard disc drive/and disc
one color graphic display terminal
one graphic line printer (DOT matrix printer)
one modem . . .
one plotter/digitizer (8 color)
all software and source code

Cost of this system is $15,000. An optional, but beneficial attachment is a Dunn camera system. This device permits the computer operator to take 8x10 instant color prints or transparencies as well as 35mm slides of all data displayed on the graphics screen. This permits the display of some defined geographic data to be scaled to some desired scale and then photographed so that an instant overlay can be produced. Cost of this system is $16,000. Thus, for a cost of $32,000 the Planning Department could implement a low cost geographic information system. It should be kept in mind, however, that micro systems do have limited analytical, storage and display capabilities and for general municipal usage there is a need for a larger mini computer.

The Planning Department has previously contracted for a Geographic Information System Study. This study identified several system components, one of which was an environmental data base. To meet certain near term planning requirements the Department contracted to have its data digitized and a geographic information data base developed. This data base could be run on the Apple computer. This approach is also compatible with the long term objective of acquiring a mini computer system which would be capable of running all component systems identified in the study. The Apple system may provide an inexpensive pilot system with interim capability for geo-process. However, such a system should not be viewed as a solution for the permanent needs of the Physical Division or the division of the Department. The mini system would require several work stations. (Digitizer, alpha numeric/graphics terminals and plotters). The Apple could serve now as the initial system and later be used as a work station to the larger mini system. In addition, the Apple system could be utilized as a stand alone system for many department functions.

For near term, effective response to Physical Planning's requirements, this approach is strongly recommended. Cost justification is clear. At present, a majority of the phycial planning staff spends at least 20 percent of its time preparing maps and analyzing data for various projects. Some staff spend as much as 50 percent of their time researching data, conducting field investigations, preparing maps and analyzing the data in order to respond to various planning projects. Each new project requires new data and information requirements and the manual preparation of new map overlays and composites. In staff time alone this represents over $100,000 annually, not to mention mapping costs, and photographic services for enlarging maps. With over $95,000 already spent on the development of a geographic

Purpose

- Prepare and maintain maps using computer-based technology
- Establish a set of information overlays for storing and filing data to produce different types of maps needed by users
- Use such a system for mapping purposes as well as input to the management decision process

Systems Approach

Offers best practical technology
in a
thorough, logical, methodical step-by-step building
of applications
to
prepare, store, retrieve and reproduce maps
and
use that data and associated facts for information purposes

Objectives

- To accrue savings in the production and maintenance environmental data
- To reduce costs related to duplication of maps and associated information
- To increase the speed of input and retrieval of map information
- To provide a stable digital data base of map information and to recall it at the original input accuracy
- To establish the ability to provide up-to-date maps in a central information center
- To improve flexibility of maps as related to scale, aerial coverage, and content
- To provide the capability to locate data quickly and make it available for decisions

Advantages

- Mapping costs can be reduced substantially
- A standard quality of maps is easier to maintain
- Updating of maps is easier and faster
- Standardization of symbols, notes and line weights is easier to achieve
- Automation provides easy and fast re-scaling of map records
- Physical requirements for storage of maps can be reduced since automated records are maintained on disc packs
- Rough sketches can be quickly converted to finished maps
- When other municipal agencies must be supported by the department, the automated mapping system provides an increased ability to respond to user needs
- Analysis of Geographic data can be quickly and efficiently done
- Opportunity and constraint maps can be produced along with capability/suitability maps

Appendix

The following maps are contained in the Appendix. All maps were produced by using computer techniques.

1. Land Use
2. Vegetation
3. Slope
4. Landform
5. Geologic Hazards
6. Soil Drainage
7. Specific Soil Slope
8. Watershed and Stream Order
9. Road Network
10. Soil Limitations for Dwellings With/Without Basements
11. Capability for Accessed Large Lot Residential Use
12. Soil Limitations for Septic Tanks
    a. base map - consultants map
    b. overlay from the demonstration project

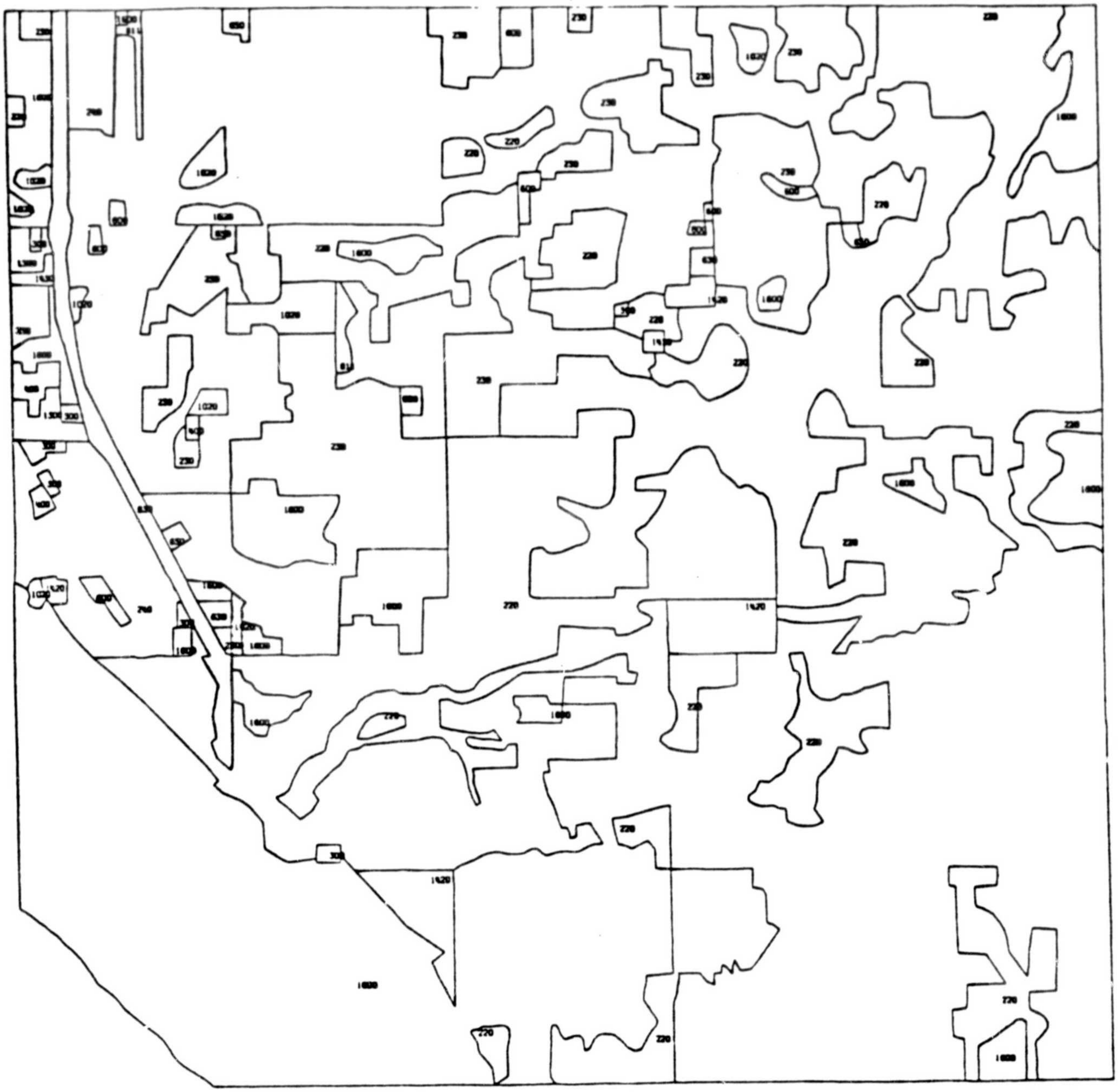

FIGURE 37(A): LAND USE

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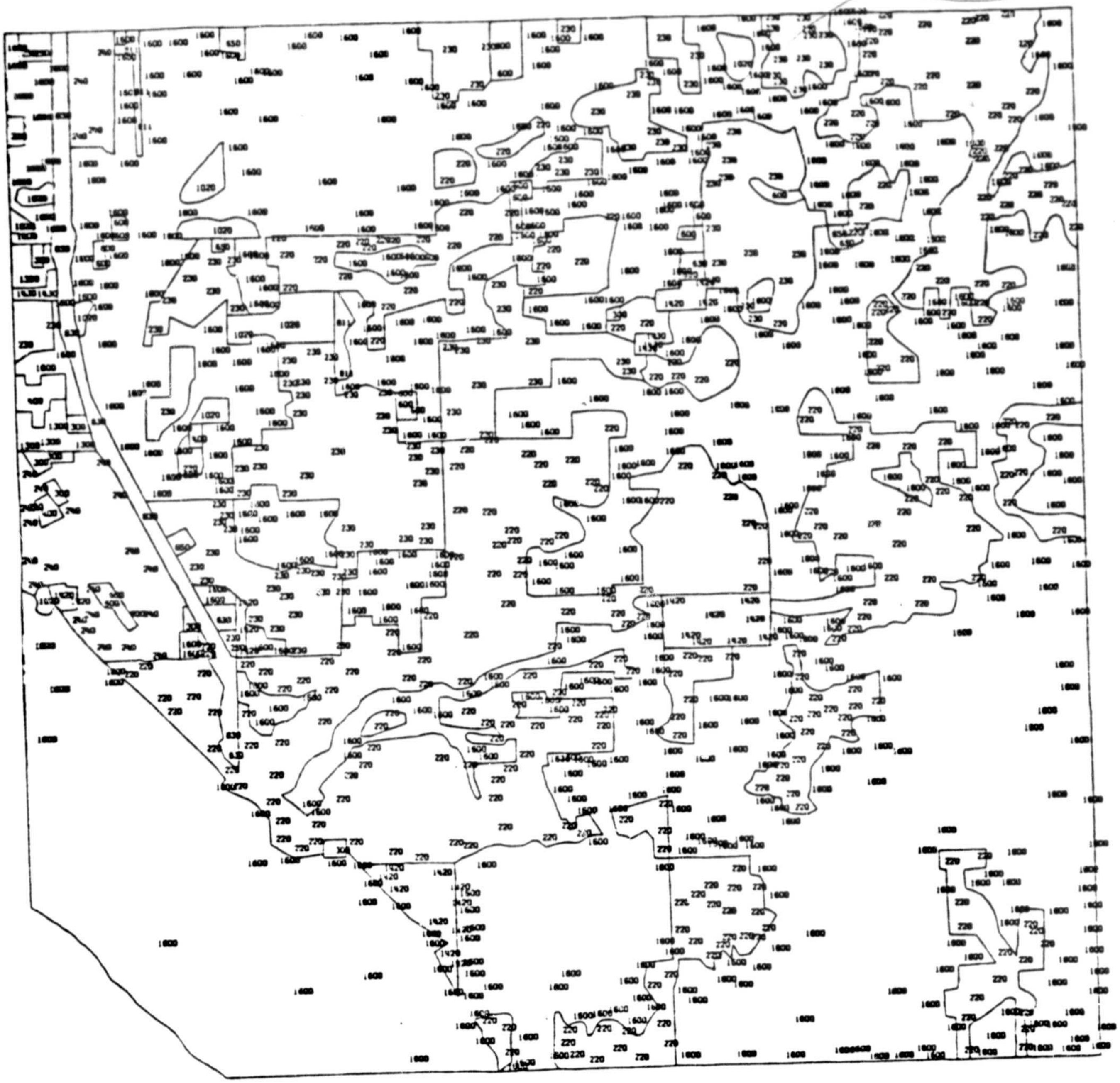

FIGURE 37(B): LAND USE

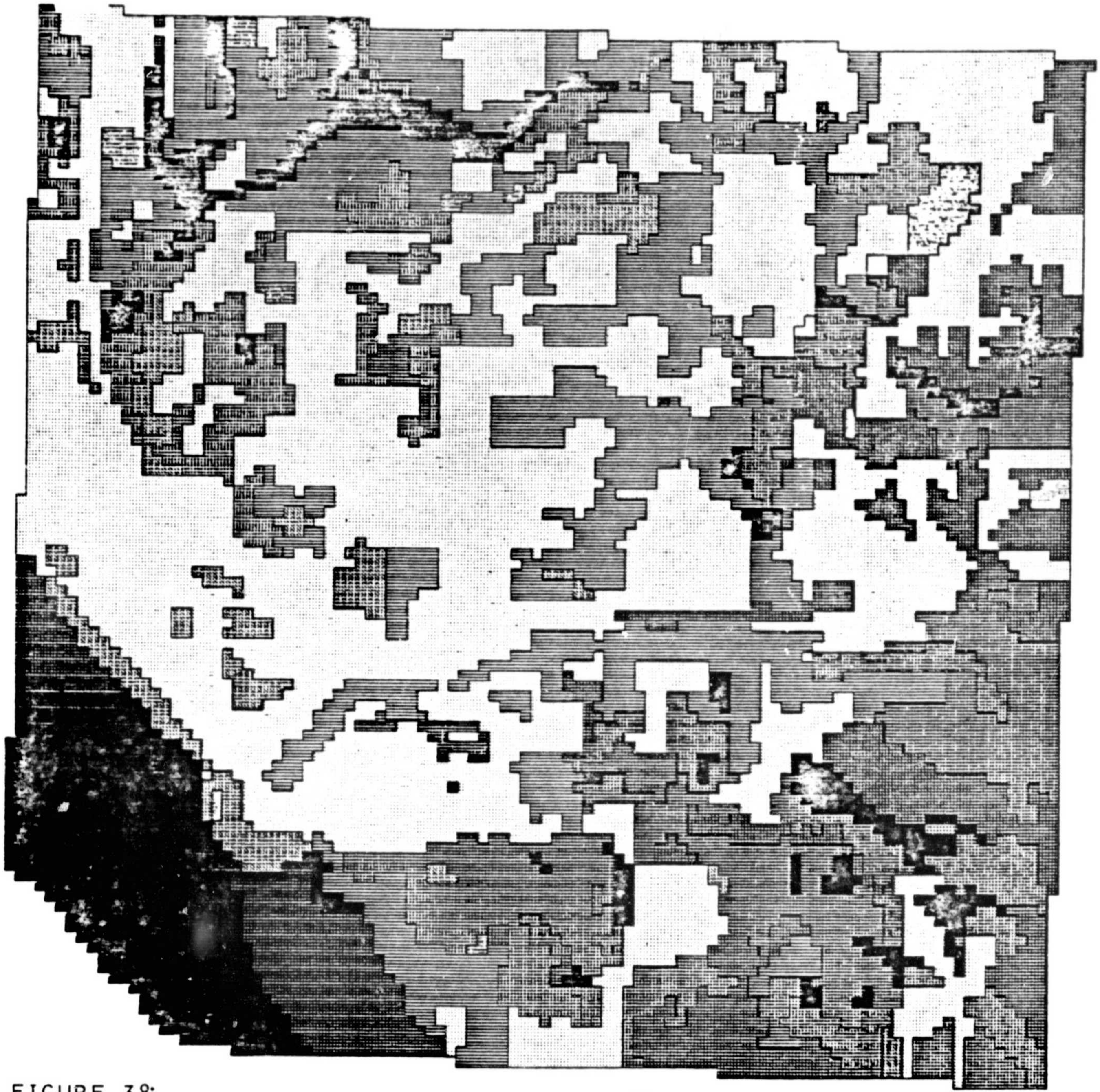

FIGURE 38:
VEGETATION

LANDSAT/AGIS INTEGRATION DEMONSTRATION
MUNICIPALITY OF ANCHORAGE, ALASKA
HILLSIDE AREA

- MUDFLAT
- SALT GRASSLAND, LOW SHRUB, TIDAL MARSH
- SPHAGNUM-SHRUB BOG
- WILLOW RESIN BIRCH
- ALDER
- TALL WHITE SPRUCE
- SHORT WHITE SPRUCE
- MEDIUM-AGED MIXED FOREST
- YOUNG MIXED FOREST
- UPLAND GRASS
- DEVELOPED
- WATER

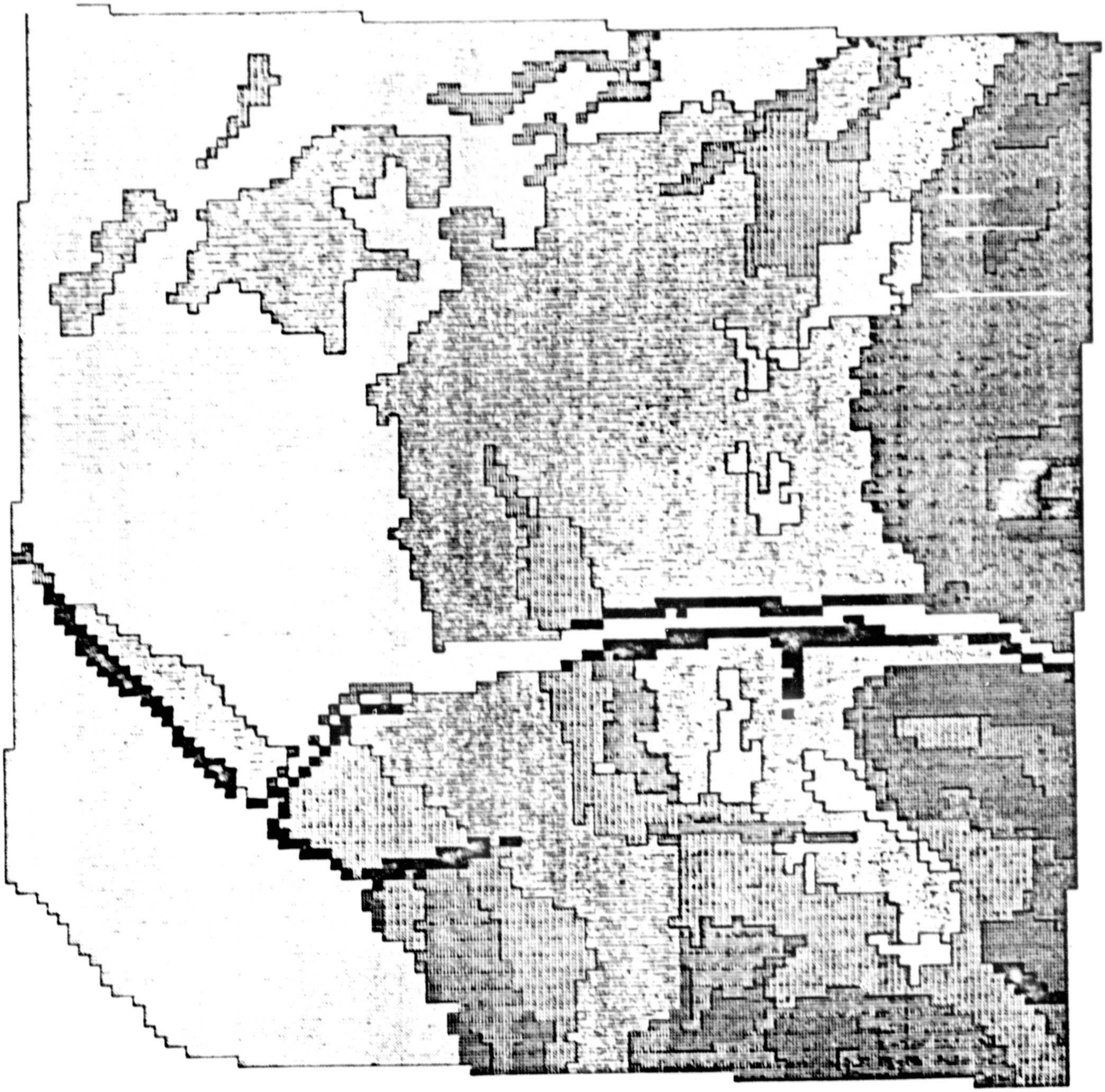

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FIGURE 39:
GENERAL SLOPE

LANDSAT/AGIS INTEGRATION DEMONSTRATION
MUNICIPALITY OF ANCHORAGE, ALASKA
HILLSIDE AREA

- 0 - 3%
- 3 - 7%
- 7 - 12%
- 12 - 20%
- 20 - 30%
- 30 - 45%
- GREATER THAN 45%

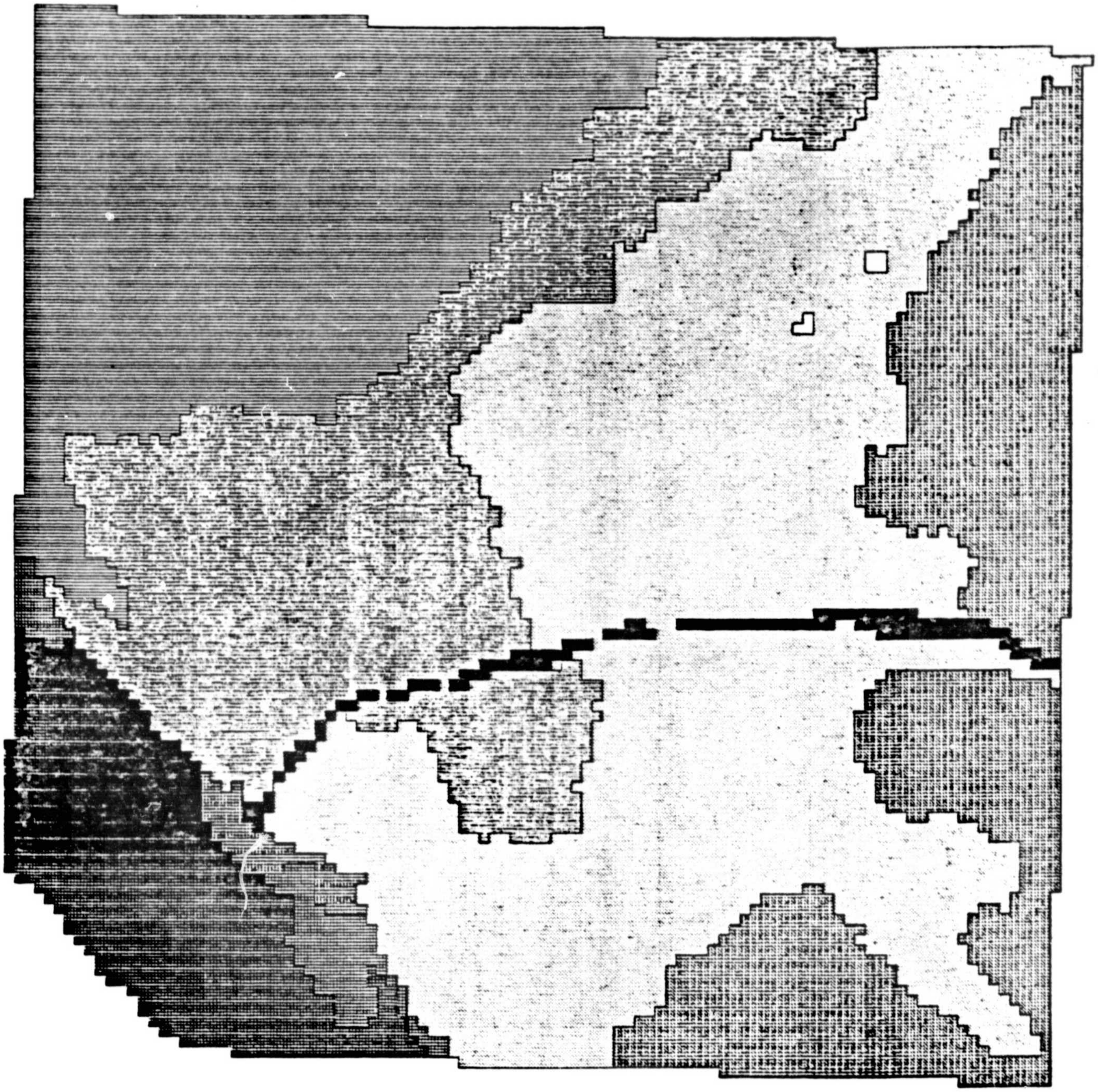

FIGURE 40:

LANDFORM TYPE

LANDSAT/AGIS INTEGRATION DEMONSTRATION
MUNICIPALITY OF ANCHORAGE, ALASKA
HILLSIDE AREA

- TIDAL FLAT
- ACTIVE FLOOD PLAIN
- COASTAL PLAIN
- ALLUVIAL FAN/CONE
- ALLUVIAL PLAIN
- TILL
- GROUND MORAINE
- END MORAINE
- WATER

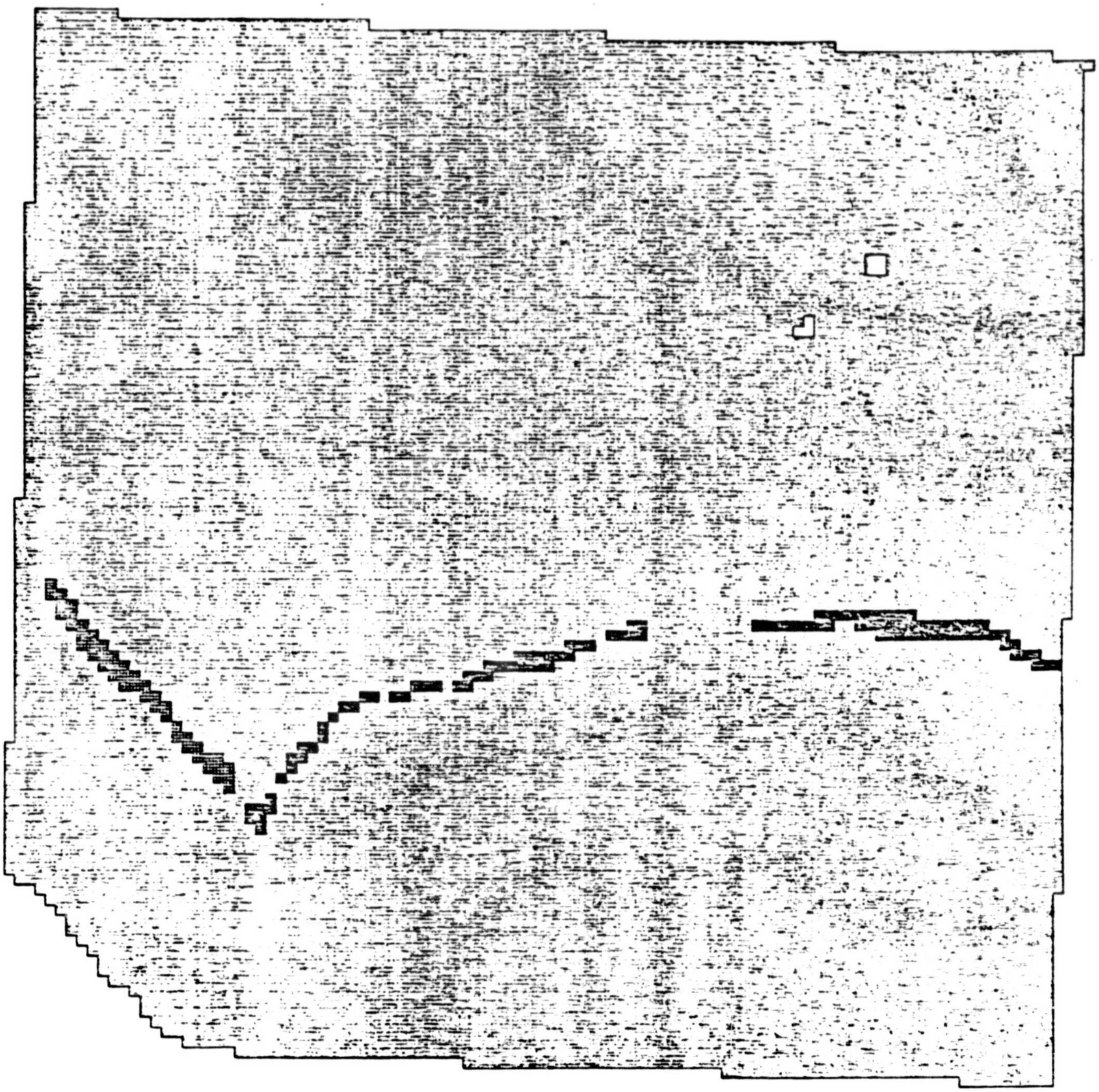

FIGURE 41:

GEOLOGIC HAZARDS

LANDSAT/AGIS INTEGRATION DEMONSTRATION
MUNICIPALITY OF ANCHORAGE, ALASKA
HILLSIDE AREA

- NO HAZARD
- POTENTIAL FLOOD ZONE
- LANDSLIDE ZONE
- WATER

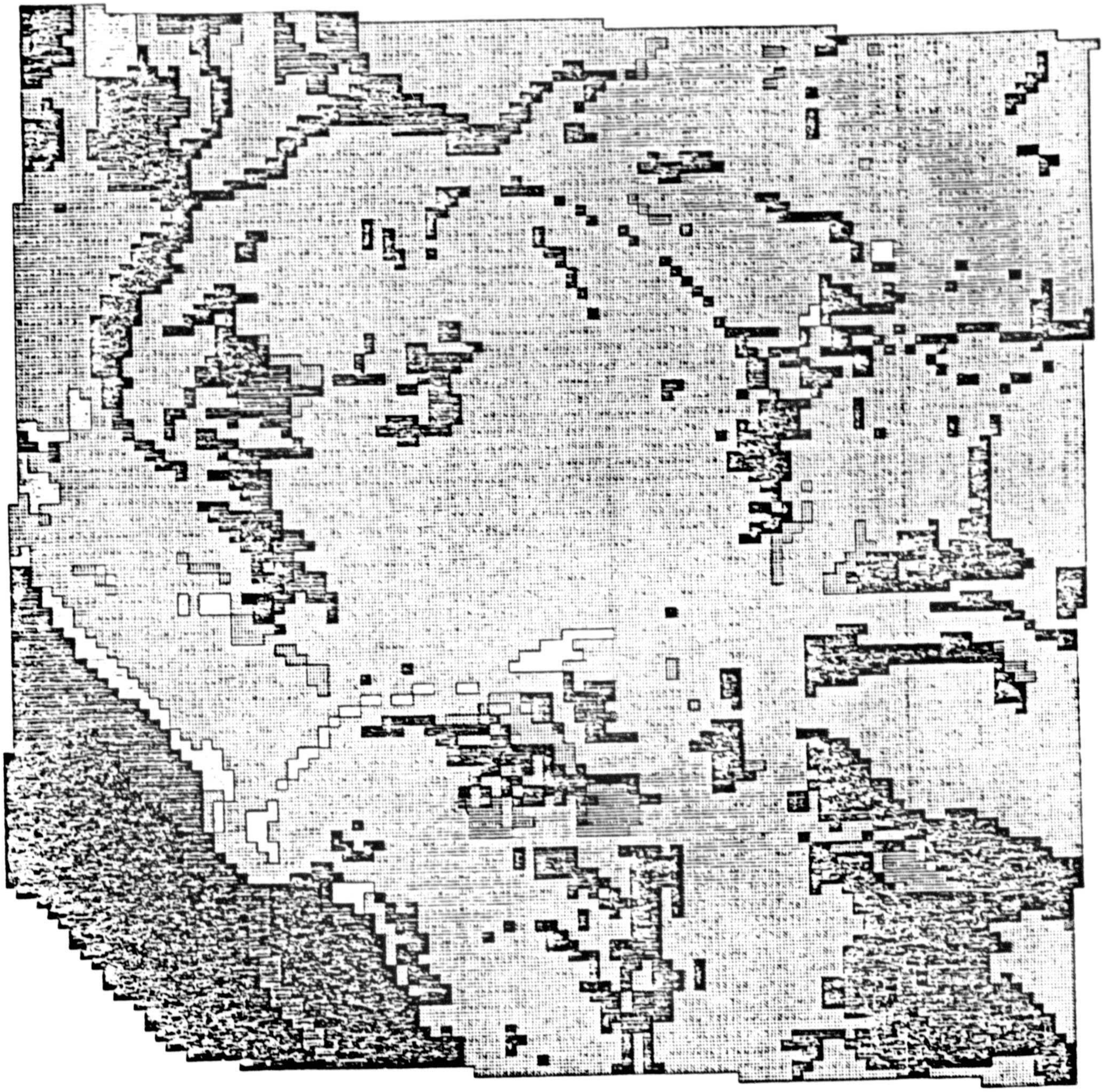

FIGURE 42:

SOIL DRAINAGE

LANDSAT/AGIS INTEGRATION DEMONSTRATION
MUNICIPALITY OF ANCHORAGE, ALASKA
HILLSIDE AREA

- EXCESSIVE
- SOMEWHAT EXCESSIVE
- WELL
- MODERATELY WELL
- SOMEWHAT POOR
- POOR
- VERY POOR
- WATER

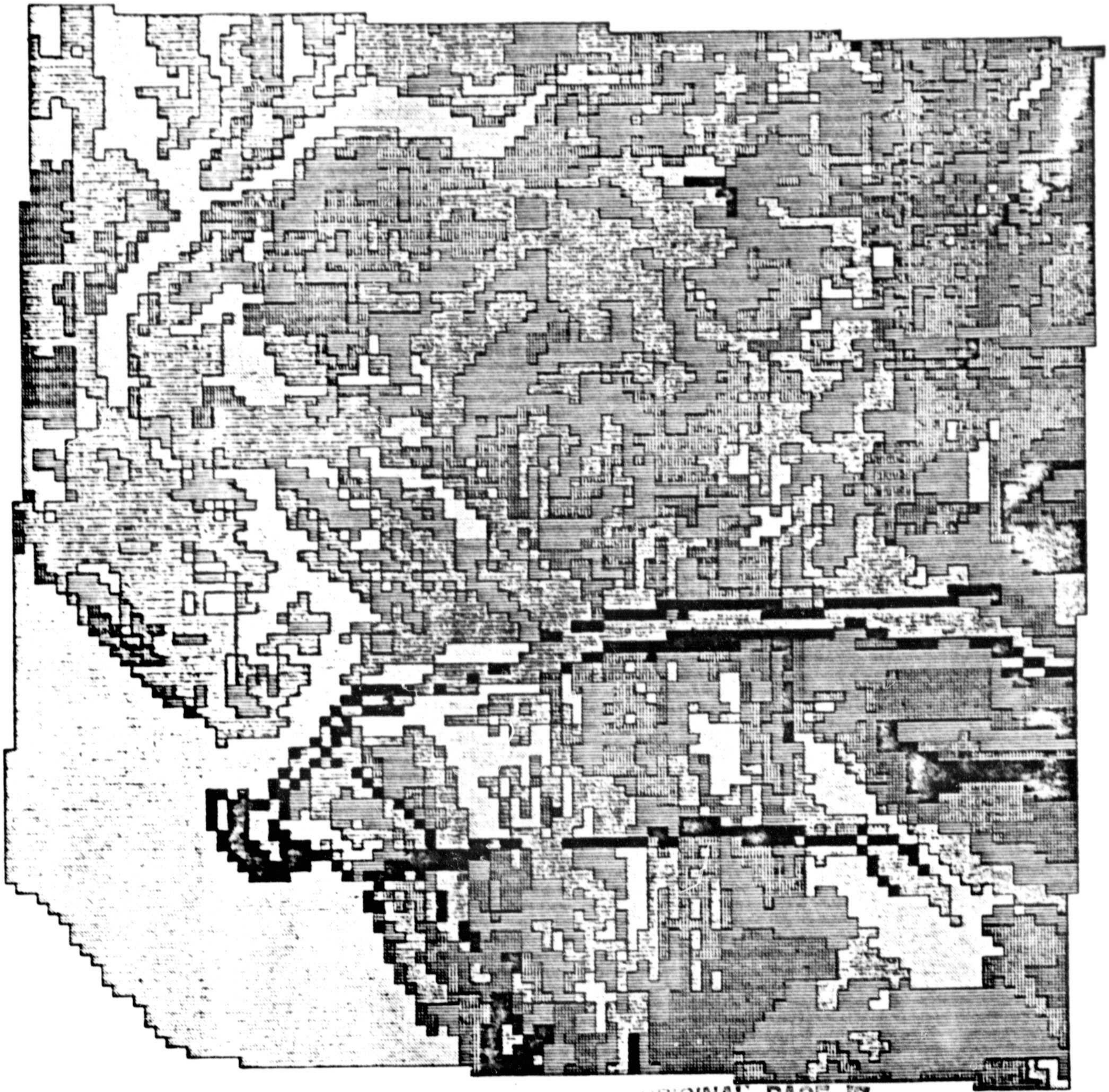

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FIGURE 43:

SPECIFIC SOIL SLOPE

LANDSAT/AGIS INTEGRATION DEMONSTRATION
MUNICIPALITY OF ANCHORAGE, ALASKA
HILLSIDE AREA

- 0 - 3%
- 3 - 7%
- 7 - 12%
- 12 - 20%
- 20 - 30%
- 30 - 45%
- GREATER THAN 45%
- WATER

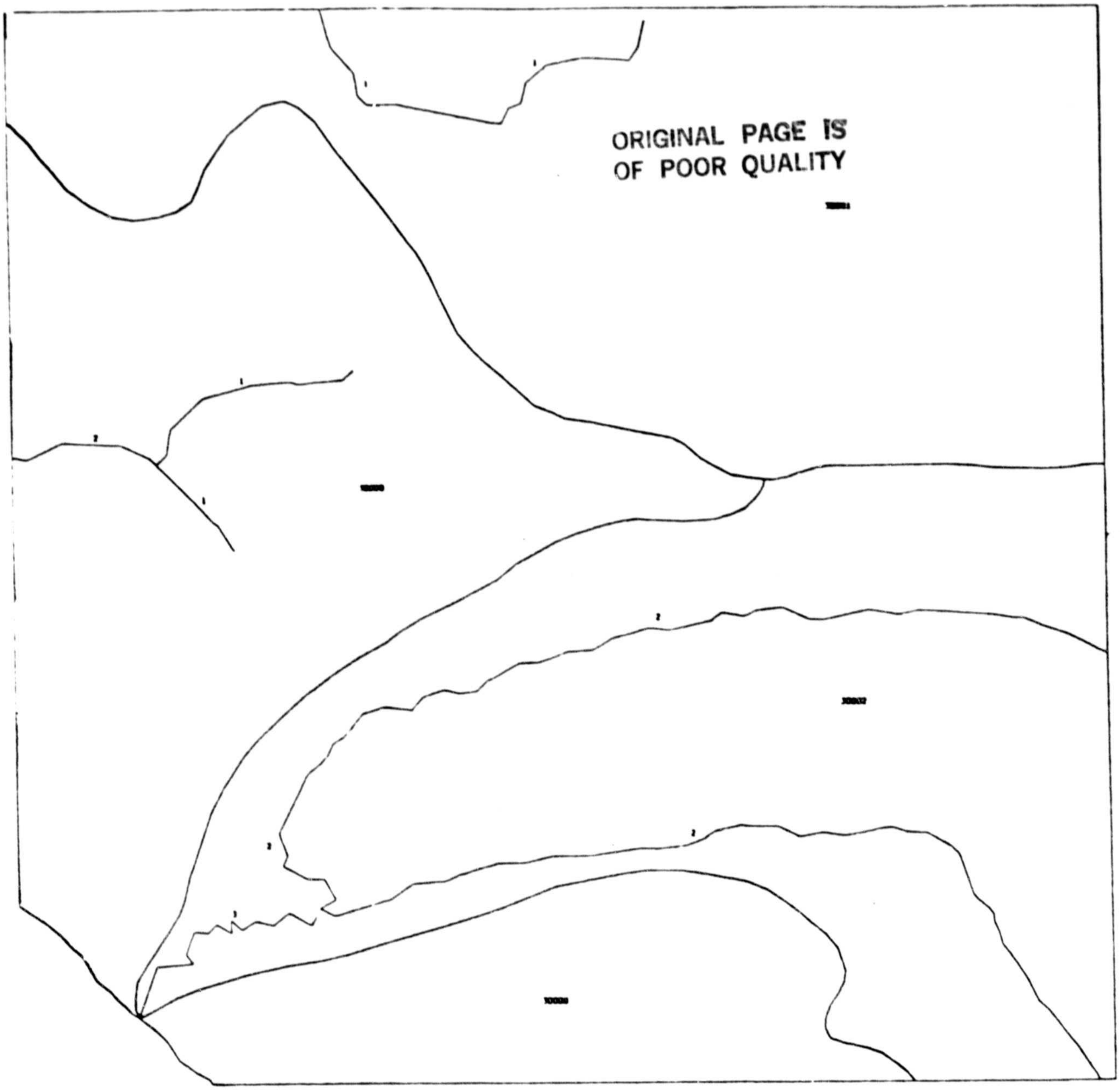

FIGURE 44: WATERSHED AND STREAM ORDER

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FIGURE 45: ROAD NETWORK

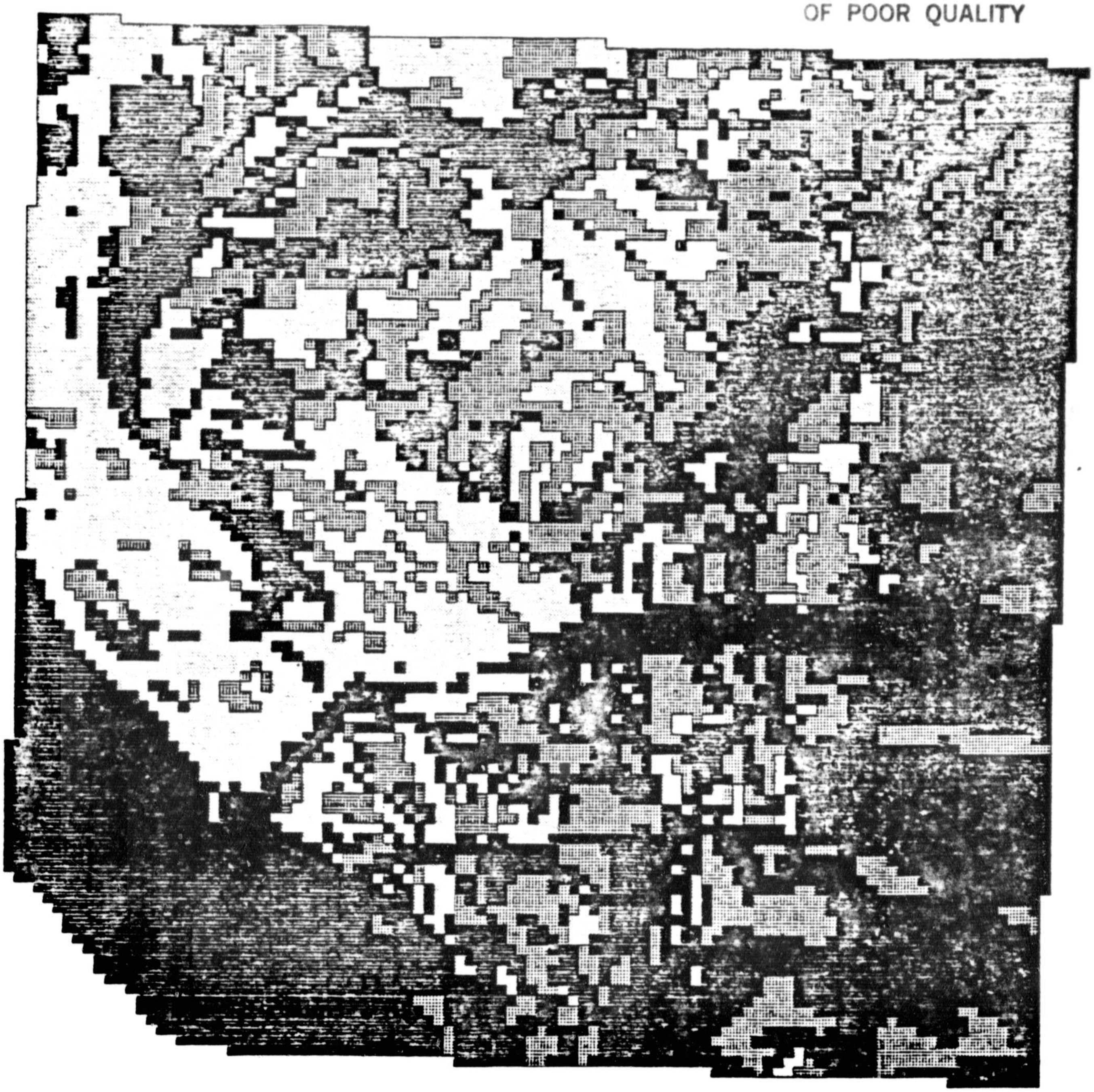

FIGURE 46:

SOIL LIMITATIONS FOR DWELLINGS
BUILDINGS WITH/WITHOUT BASEMENTS

LANDSAT/AGIS INTEGRATION DEMONSTRATION
MUNICIPALITY OF ANCHORAGE, ALASKA
HILLSIDE AREA

- SLIGHT
- MODERATE
- SEVERE
- WATER

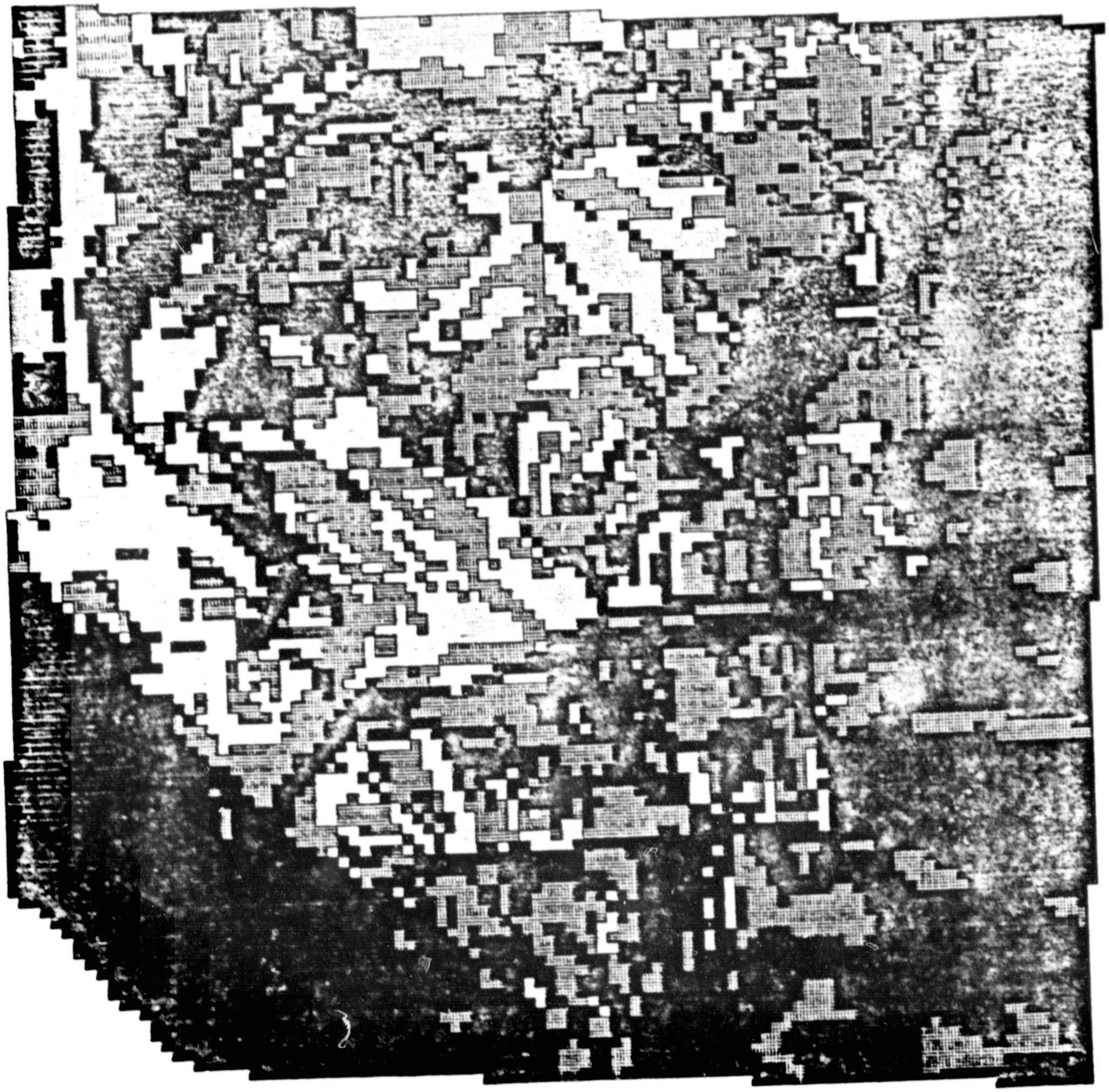

FIGURE 47:
CAPABILITY FOR ACCESSED LARGE LOT
RESIDENTIAL DEVELOPMENT

LANDSAT/AGIS INTEGRATION DEMONSTRATION
MUNICIPALITY OF ANCHORAGE. ALASKA
HILLSIDE AREA

□ HIGH
■ MODERATE
■ LOW
■ VERY LOW

FIGURE 48:

SOIL LIMITATIONS FOR SEPTIC TANKS

LANDSAT/AGIS INTEGRATION DEMONSTRATION
MUNICIPALITY OF ANCHORAGE, ALASKA
HILLSIDE AREA

- SLIGHT
- MODERATE
- SEVERE
- WATER

LEGEND

NOT SUITABLE FOR INDIVIDUAL ON-SITE

FIGURE 49

Arctic Environmental Engineers
Anchorage, Alaska

HILLSIDE WASTEWATER DISPOSAL STUDY

MAP OF SUITABILITY FOR INDIVIDUAL ON-SITE WASTEWATER TREATMENT

APPENDIX M

Georeferenced Landsat Classified Images for GIS Integration

INTRISCA Project
May 1981

Charlotte Carson-Henry

Introduction

As a final phase in the INTRISCA Project analysis of 1978 Landsat imagery, a test GIS integration was performed by the Environmental Systems Research Institute (ESRI). This integration utilized two test sites, one from each of the two 1978 scenes classified — the Anchorage/Eastern scene and the Susitna scene — along with ancillary data provided by various Alaska personnel and agencies.

ESRI had generated a data base registered to UTM; the inclusion of Landsat classified data in this data base therefore required that the Landsat data be likewise registered to UTM. Toward this end, ESRI worked with the Alaska users and with Ames personnel to select two test sites that could serve both as a test of the vertical data integration as well as sites on which accuracy assessments could be made by the Alaska users. ESRI obtained exact UTM coordinates defining the boundaries of the two test sites and provided Ames personnel with those coordinates. The two test sites were then registered to the UTM map base, using the boundary coordinates to define the spaces into which the classified Landsat data sets were registered.

The following papers describe the digital processing steps that accomplished this georeferencing of the Big Lake portion of the Susitna scene and the Hillside portion of the Eastern or Anchorage scene to a UTM map base.

Georeferencing a Portion of the Susitna Image

INTRISCA Project

Alaska/ESRI GIS Integration Effort

Charlotte Carson-Henry

March 1981

BIG LAKE TEST SITE

I. Control Point Selection

1. Control points were selected using the IDIMS display, the image LLSUS (line-by-line deskewed rotated Susitna mosaic, 1978 data used for classification) and four USGS quad sheet maps at 1:63,360 scale. The study area had been previously located on a 1:250,000 scale map using UTM coordinates provided by ESRI. On this second iteration, a total of nineteen control points were selected; some were identical to or within several pixels of previously-used control points, but many were totally new point locations. Those which were identical to old control points retained the name originally assigned; those points that were within several pixels of old control points were assigned names similar to the names used previously, except that an "A" was added to the name. Those points which were altogether new were assigned names including numbers beginning at, and ascending from, twenty.

   Control point locations were marked concurrently on the 1:63,360 maps as they were located on the screen. Image coordinates for each point were also recorded, along with a description of the location of the point, the quality of the point, and an evaluation of any move of the point if required.

2. A Text Editor file was then created on IDIMS, containing the control point names and the sample/line coordinates noted while viewing the image on the display screen.

```
:HELLO CARSON,NDAKOTA.GIS
welcome message
:EDITOR
welcome message
/ADD
```

	Name	Samp/Line	(NOT PART OF TEXT FILE:) Description	Qual.	Move
1	BL1A	3183 1603	(Small lake SW of Bench Lake)	Excel.	W 1
2	BL20	3100 1544	(Small lake SW of Deception Creek, Section 35)	Good	W 1
3	BL21	3014 1596	(Lake in Section 18)	Excel.	none
4	BL10	2964 1524	(NW point of lake, E of Nancy Lake, Section 25)	Excel.	SE
5	BL22	2902 1546	(Peninsula in Lake Nancy)	Good	? maybe W
6	BL11A	2949 1610	(Small lake, Section 14)	Good	E 1
7	BL9A	2949 1714	(Pothole W of Horse Lake N shore, Section 11)	Excel.	none
8	BL23	3048 1694	(W. Beaver Lake, NW shore inlet)	Good	none
9	BL3A	3151 1713	(Y intersection, Hwy 3, Section 12)	Good	N or W
10	BL24	3219 1680	(Lake in Section 4)	Good	none or E 1
11	BL4	3177 1789	(3rd in vertical string of 4 lakes, Sec. 31)	Good	N 1, E 1
12	BL5A	3117 1829	(S. shore 3-Mile Lake)	Good	N 1, E 1
13	BL25	3057 1798	(SW corner molar-shaped lake, Section 33)	Good	none
14	BL6A	2999 1818	(Lake Marion)	Good	none
15	BL26	2987 1857	(Small lake, SE of Lake Marion, Section 13)	Excel.	none
16	BL27	2884 1844	(Tiny lake, Section 8)	Excel.	none
17	BL12A	2921 1779	(Water, NE Flat Lake)	Good	W 1 or none
18	BL28	3050 1752	(Lake in Section 21)	? Good	???
19	BL29	3009 1769	(Island tip, Section 30)	Good	none
20	//				

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/LISTALL,OFFLINE
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/EXIT
:BYE
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PAGE 1 HEWLETT-PACKARD 32201A.7.04 EDIT/3000 MON, MAR 9, 1981, 9:28 PM (C

1	BL1A	3183	1603
2	BL20	3100	1544
3	BL21	3014	1596
4	BL10	2964	1524
5	BL22	2902	1546
6	BL11A	2949	1610
7	BL9A	2949	1714
8	BL23	3048	1694
9	BL3A	3151	1713
10	BL24	3219	1680
11	BL4	3177	1739
12	BL5A	3117	1829
13	BL25	3057	1798
14	BL6A	2999	1818
15	BL26	2987	1857
16	BL27	2884	1844
17	BL12A	2921	1779
18	BL28	3050	1752
19	BL29	3009	1769

Big Lake Control Points
Text Editor File

(Points taken from LLSUS)

Second run

Filename: BLIMGCP2.NDAKOTA.GIS

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Table 34: Big Lake Control Point File Listing

The control points selected on the IDIMS screen and entered into a text file were then digitized using the GES (Geographic Entry System) software on the HP 3000. In order to digitize control points in GES, a geoblock must be defined (area within which digitizing will occur), files must be named, and maps must be registered to the digitizer.

II. Digitizing Control Points

:HELLO CARSON,NDAKOTA.GIS
:RUN GES.PUB

(System prompts with questions regarding terminal type, digitizer type, and with Register Menu routines. TALOS digitizer used in this application.)

(Abbreviated prompts:)

Geoblock Directory File Name?	BLGEOBLK	
Prompt for Label Positions?	N	(This option used with polygons)
Six-char. Geoblock Name?	BGLAKE	
Geoblock Dimensions; Lat/Lon of Lower Left Corner?	61 25 00 N 150 05 00 W	
Width, Height (in minutes)?	28,20	
Area File Capacity?	default	
Tolerance?	default	
Overlay Number?	1	
OV Type?	P	(Point)

(Register Map Routines)
For Tyonek B-1, used LL point of 61 25 00 N ; 150 05 00 W
Distance between LL and Upper Reg. Pt. of 5 minutes
(Upper Reg. Pt. — MAPREG2 — 61 30 00 N ; 150 05 00 W)

MAPREG3: 61 30 00 N ; 150 00 00 W
MAPREG4: 61 25 00 N ; 150 00 00 W

Tested points; registration very good. Defaulted out of Register Map routines.

ENTER	
Class ID?	1
Spark point, Point ID?	BL27

Defaulted out of ENTER mode; BL27 only CP on that map.

Register Map for Anchorage B-8 quad sheet:
Lower point: 61 25 00 N ; 150 00 00 W
Distance between two points: 5 minutes
(Upper Reg. Pt. 61 30 00 N ; 150 00 00 W)

MAPREG3: 61 30 00 N ; 149 50 00 W
MAPREG4: 61 25 00 N ; 149 50 00 W
MAPREG5: 61 30 00 N ; 149 40 00 W
MAPREG6: 61 25 00 N ; 149 40 00 W

Map registration looked good, both in transformation and in test point mode.

(Spark ENTER on menu)
Class ID? 2
Spark point; point ID? BL26
Spark point; point ID? BL5A

(Spark DEFAULT on menu to exit point entry mode.)

Register Map routine for Anchorage C-8 quad sheet map:
Lower point: 61 30 00 N ; 150 00 00 W
Distance between two points: 15 minutes
(Upper point 61 45 00 N ; 150 00 00 W)

MAPREG3: 61 35 00 N ; 149 55 00 W
MAPREG4: 61 40 00 N ; 149 55 00 W
MAPREG5: 61 40 00 N ; 149 45 00 W
MAPREG6: 61 35 00 N ; 149 45 00 W
MAPREG7: 61 30 00 N ; 149 40 00 W
MAPREG8: 61 45 00 N ; 149 40 00 W

(Control points covered nearly entire map, so registration points were more widely disbursed for a better fit. Map registration acceptable, based upon testpoint mode, but not as good as that of small sections of previous two maps registered.)

(Spark ENTER on menu)
Class ID? 3
Spark point; point ID? BL1A
" " BL20
" " BL21
" " BL10
" " BL11A
" " BL9A
" " BL23
" " BL3A
" " BL24
" " BL4
" " BL25
" " BL6A
" " BL12A
" " BL28
" " BL29

(Spark DEFAULT on menu)

Register Map routines for map Tyonek C-1:
Lower point: 61 35 00 N ; 150 05 00 W
Distance between upper, lower points: 10 minutes
(Upper point: 61 45 00 N ; 150 05 00 W)

MAPREG3: 61 45 00 N ; 150 00 00 W
MAPREG4: 61 35 00 N ; 150 00 00 W

Based on map registration test points, registration was good.

(Spark DEFAULT on menu)

(Spark ENTER on menu)
Class ID? 4
Spark point; point ID? BL22

(Defaulted out of ENTER mode; BL22 only CP on that map.)

(Spark STOP on menu to exit GES.)

The control points here digitized will subsequently be transformed into the 80-metre grid to be built in the next step, and that transformation will be used by the IDIMS function REGISTER in creating the georeferenced output image.

III. Construction of 80-metre UTM Grid

1. The program ALLCOORD on the HP 3000 was then used to construct a grid of 80-metre cells in a UTM base. The digitized control points were subsequently transformed into this grid.

```
:HELLO CARSON,NDAKOTA.GIS
welcome message
:RUN ALLCOORD.UTILS.IDIMS
welcome message

(Abbreviated prompts:)

Line printer listing of output required?        Y
Input Coordinates are in the form of?           P       (GES control points)
Name of Geoblock File?                          BLGEOBLK
Name of desired Geoblock?                       BGLAKE
Class ID   (CR for all)?                        CR
Output text file desired?                       Y
Name of file to receive output?                 BLTOTSEC
Capacity limit?                                 CR
Store coordinates as?                           S       (Total seconds lat/lon)
State Plane Zone  (CR to omit)                  6176

        6176UTM F     ALASKA,  ZONE 4

        XMIN=    -540124.      YMIN=    221340.
        FINISHED;      20 POINTS PROCESSED
END OF PROGRAM

:RUN ALLCOORD.UTILS.IDIMS
welcome message

(Abbreviated prompts:)

Line printer listing of output required?        Y
Input coordinates are?                          F       (Text file)
Input coordinates are in the form of?           S       (Total seconds)
Name of file containing input coordinates?      BLTOTSEC
Output text file desired?                       Y
Name of file to receive output?                 BLTSUTM
Capacity limit?                                 CR
Store coordinates as?                           G       (Grid)
State Plane Zone  (CR to omit)                  CR
UTM coordinates of X,Y of grid origin?          340000,6840000
Dimension of grid cell, in metres?              80

        XMIN=      3974.   YMIN=      -59.
        XMAX=      4226.   YMAX=      246.

        FINISHED;      20 POINTS PROCESSED.
END OF PROGRAM
:
```

Since the first point in the digitized control point file, point BL27, falls in UTM Zone 5, the system places the entire set of control points in Zone 5, while all but two of the points are actually in Zone 6. To work around this problem, the Text Editor was used to move the first point to the end of the file; the result of so doing was to allow the first point encountered in the file to be in Zone 6, so that all points were placed in the appropriate UTM zone.

```
:EDITOR
welcome message
/TEXT BLTOTSEC                              (accessing ALLCOORD output)
/JOIN BLTOTSEC                              (appends 2nd copy, same file)
/DQ 1                                       (deletes record #1; no echo)
/LIST ALL
/DQ 22/40                                   (deletes records 22/40: records
                                             #2 through last of 2nd copy)
/LIST ALL                                   (demonstrates that BL27 is at
                                             the end of the list)

/KEEP BGTOTSEC,UNN
/EXIT
:

:RUN ALLCOORD.UTILS.IDIMS
welcome message

Line printer listing of output required?        Y
Input coordinates are?                          F       (Text file)
Input coordinates are in form of?               S       (Total seconds)
Name of file containing input coordinates?      BGTOTSEC
Is an output text file required?                Y
Name of file to receive output?                 BG80M
Capacity limit?                                 CR
Store coordinates as?                           G       (Grid)
State Plane Zone  (CR to omit)?                 6176

      6176UTM F      ALASKA, ZONE 4

Enter UTM coordinates of grid origin?           340000,6840000
Dimension of grid cell, in metres?              80

      XMIN=    -19.    YMIN=     -54.
      XMAX=    247.    XMIN=     251.

      FINISHED;  20 POINTS PROCESSED.
END OF PROGRAM
:
```

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WED, MAR 11, 1981, 11:49 AM

INPUT COORDINATES READ AS TOTAL SECONDS
INPUT TEXT FILE BGTOTSEC

OUTPUT TEXT FILE BG80M
COORDINATES STORED AS UTM GRID
STATE PLANE ZONE IS 6176UTM F ALASKA, ZONE 4
UTM COORDINATES OF GRID ORIGIN 340000. 6840000.
SIZE OF GRID CELL IN METERS 80.
UTM ZONE 6

	COORDINATES		TOTAL SECONDS		UTM (METERS)	
BL2[illegible]	61 [illegible]	149 54'53"	-539493	221340	344796.	6819892.
BL[illegible]	61 [illegible]	149 45'56"	-539155	221394	352767.	6821217.
BL[illegible]	61 [illegible]	149 46'24"	-5391[illegible]	222080	353223.	6842449.
BL[illegible]	61 [illegible]	149 46'51"	-5[illegible]51	221935	357995.	6837788.
BL[illegible]	61 [illegible]	149 38'35"	-538715	221750	359761.	6831454.
BL[illegible]	61 [illegible]	149 55'51"	-5[illegible]751	222139	345029.	6844358.
BL[illegible]	61 [illegible]	149 52'35"	-539555	221957	347669.	6838880.
BL[illegible]	61 [illegible]	149 57' 6"	-539826	221925	343640.	6838069.
BL[illegible]	61 [illegible]	149 57'17"	-539837	221670	343124.	6830377.
BL[illegible]	61 [illegible]	149 54' 1"	-539641	221425	345572.	6822466.
BL[illegible]	61 [illegible]	149 50' 6"	-539406	221472	349207.	6823786.
BL[illegible]	61 [illegible]	149 50'23"	-539423	221724	349295.	6831590.
BL[illegible]	61 [illegible]	149 41'45"	-538905	221490	355629.	6824029.
BL[illegible]	61 [illegible]	149 53'27"	-539667	221521	340992.	6825672.
BL[illegible]	61 [illegible]	149 53'10"	-539599	221540	346450.	6826014.
BL[illegible]	61 [illegible]	149 50'23"	-539423	221584	349107.	6827260.
BL[illegible]	61 [illegible]	149 43'22"	-539002	221572	355432.	6829717.
BL[illegible]	61 [illegible]	149 57'17"	-539837	221673	343128.	6830377.
BL[illegible]	61 [illegible]	150 0'15"	-540015	222079	341080.	6842954.
BL[illegible]	61 [illegible]	150 2' 4"	-540124	221364	338448.	6820925.

STATE PLANE (FEET) TRANSFORMED INPUT

514907.	2734148.
540865.	2739695.
539162.	2809354.
555495.	2794798.
562167.	2775944.
512005.	2814370.
521489.	2796815.
508405.	2793548.
507891.	2768262.
517419.	2742783.
528869.	2747579.
527921.	2773168.
553098.	2749494.
501600.	2752519.
519436.	2754465.
527955.	2758951.
548315.	2767955.
507891.	2768262.
499276.	2809184.
493980.	2736577.

Table 35. Big Lake ALLCOORD Listing

On the first runs of TRNSFORM to generate the transformation to be used by REGISTER, several points emerged with residuals higher than .9; these points were evaluated and decisions were made regarding the movability of the points in the image control point file. As a result, the Text Editor was used to change the values of two points. One change was later negated or reversed due to the behavior of all points on subsequent TRNSFORM runs. The final decision was that all points would remain as originally chosen and noted, except BL25, which was changed as follows:

BL25 3056.5 1798

The file was Kept, in Text Editor, as BLIMGCP2.

In addition, two points were subsequently deleted from the transformation: these deletions were performed during the interactive running of the TRNSFORM program.

IV. Computing Transformation

:RUN TRNSFORM.UTILS.IDIMS
welcome message

INSTRUCTIONS?	N	
Origin for Source Control Points?	3	(Text file)
X,Y Biases?	0,0	
Name of text file?	BG80M	
Origin for Destination Control Points?	3	
X,Y Biases?	0,0	
Name of text file?	BLIMGCP2	
Print matching points on line printer?	Y	
Enter name of TRNSMTX file?	T3BLTMTX	
File open error, etc.	B	(Build)
Capacity?	100	
Desired filename or CR for T3BLTMTX?	CR	

First- and second-order fits were computed. It was decided to delete points.

Do you wish to alter points?	Y	
Add, change, delete, list, or end?	D	
Line number to delete?	1	(point BL26)
Add, change, delete, list, or end?	E	

First- and second-order fits were again computed, without this point. Another point was selected for deletion, hopefully without jeapardizing the point distribution.

Do you wish to alter points?	Y	
Add, change, delete, list, or end?	D	
Line number to delete?	14	(point BL29)
Add, change, delete, list, or end?	E	

```
     RESIDUAL MEANS:      .364315     .299101

NUMBER       A(N)              B(N)

   1     1586.81          2887.39
   2     1.07568          .918829 E-01
   3     -.603553 E-01    1.30376

Do you wish to alter points?                        N
Do you wish this to be the highest order
    transform?                                      N

     RESIDUAL MEANS:      .303165     .232048

NUMBER       A(N)              B(N)

   1     1586.60          2887.90
   2     1.08382          .912392 E-01
   3     -.530228 E-01    1.29289
   4     -.360800 E-04    -.630983 E-05
   5     -.305048 E-04    .367189 E-04
   6     -.130868 E-04    .189268 E-04

Do you wish to alter points?                        N
Do you wish this to be the highest order
    transform?                                      Y
Enter name of transmatrix record?                   T3BLTMTX
Enter description of transmatrix record?            Control X, followed by:

                                                    T3 17 OF 19 NEW CPS 31181 CCH

Do you wish the inverse transform?                  N
END OF PROGRAM
:

:RELEASE T3BLTMTX
:BYE
```

(The RELEASE command allows the file T3BLTMTX to be accessed from other log-on accounts; the REGISTER program is an IDIMS function and must access the transmatrix file from an IDIMS account/log-on.)

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POINT	SX	SY	DX	DY	TX	TY	RX	RY
1 BL26	60	251	2987	1857	2988	1854	-1.3	3.0
2 BL6A	160	235	3117	1829	3117	1830	.0	-1.1
3 BL20	165	-31	3100	1544	3100	1544	-.3	.3
4 BL1A	225	28	3183	1603	3183	1603	-.3	.2
5 BL24	247	101	3219	1680	3219	1680	.3	-.0
6 BL10	63	-54	2964	1524	2964	1524	-.4	-.2
7 BL21	96	14	3014	1596	3014	1596	.3	-.0
8 BL11A	45	24	2949	1610	2949	1610	.1	-.0
9 BL9A	39	120	2949	1714	2949	1714	-.4	-.0
10 BL5A	71	219	2999	1818	3000	1818	-.8	-.4
11 BL25	115	203	3057	1798	3056	1798	1.0	-.2
12 BL23	116	105	3048	1694	3049	1693	-.5	1.0
13 BL4	208	200	3177	1789	3177	1789	.3	-.2
14 BL12A	12	179	2921	1779	2920	1779	1.1	-.1
15 BL29	81	175	3009	1769	3008	1770	.5	-1.3
16 BL28	114	159	3050	1752	3050	1751	-.4	.6
17 BL3A	193	129	3151	1713	3151	1713	.3	-.5
18 BL22	14	-37	2902	1546	2902	1546	.4	-.1
19 BL27	-19	238	2884	1844	2884	1845	.2	-1.0

RESIDUAL MEANS = .464278 .537906

First-order transformation

(Decision to move points was based on this output.)

POINT	SX	SY	DX	DY	TX	TY	RX	RY
1 BL6A	160	235	3117	1829	3117	1830	-.1	-.6
2 BL20	165	-31	3100	1544	3100	1544	-.2	.1
3 BL1A	225	28	3183	1603	3183	1603	-.2	.0
4 BL24	247	101	3219	1680	3219	1680	.3	-.1
5 BL10	63	-54	2964	1524	2964	1524	-.3	-.4
6 BL21	96	14	3014	1596	3014	1596	.3	-.1
7 BL11A	45	24	2949	1610	2949	1610	.1	.0
8 BL9A	39	120	2949	1714	2949	1714	-.5	.2
9 BL5A	71	219	2999	1818	3000	1818	-1.0	.1
10 BL25	115	203	3057	1798	3056	1798	.4	.2
11 BL23	116	105	3048	1694	3049	1693	-.6	1.2
12 BL4	208	200	3177	1789	3177	1789	.2	.1
13 BL12A	12	179	2921	1779	2920	1779	.0	.4
14 BL29	81	175	3009	1769	3009	1770	.4	-.9
15 BL28	114	159	3050	1752	3050	1751	-.5	.8
16 BL3A	193	129	3151	1713	3151	1713	.3	-.4
17 BL22	14	-37	2902	1546	2902	1546	.4	-.2
18 BL27	-19	238	2884	1844	2884	1844	-.1	-.3

RESIDUAL MEANS = .366625 .33945

First-order transformation,

after point BL26 deleted

Table 36. Big Lake First-order Transformations

POINT		SX	SY	DX	DY	TX	TY	RX	RY
1	BL[illegible]	[illegible]	[illegible]	3117	[illegible]	3117	[illegible]	[illegible]	-.7
2	[illegible]	[illegible]	-31	[illegible]	[illegible]	[illegible]	1544	-.2	.1
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-.2	.0
4	[illegible]	[illegible]	101	[illegible]	[illegible]	3219	[illegible]	[illegible]	-.1
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1524	-.3	-.4
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.3	-.1
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1610	.1	-.0
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1714	-.4	.2
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-.9	-.0
10	[illegible]	115	[illegible]	3057	[illegible]	3056	1798	.4	.1
11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3049	1693	-.5	1.1
12	[illegible]	[illegible]	[illegible]	3177	[illegible]	3177	[illegible]	.3	-.0
13	BL12A	[illegible]	[illegible]	2921	[illegible]	[illegible]	[illegible]	1.0	.3
14	[illegible]	114	[illegible]	[illegible]	[illegible]	[illegible]	1751	-.4	[illegible]
15	BL3A	[illegible]	[illegible]	3151	[illegible]	3151	[illegible]	.3	-.4
16	[illegible]	14	-37	[illegible]	[illegible]	2902	[illegible]	.4	-.2
17	[illegible]	-1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-.5

RESI[illegible] = .3[illegible]315 .2[illegible]

FINAL TRANSFORMATION

First-order transformation

After deletion of points BL26 and BL29, and after Text File BLIMGCPS modified with new coordinates for point BL25.

Table 37. Big Lake Final Transformation Listing

V. Creating Georeferenced Image

The IDIMS function REGISTER, when used in the mode about to be illustrated, accesses a pre-existing transformation matrix file and uses the coefficients stored in that file to create the output image. In this case, the transformation matrix reflects the relationship between the classified image and the 80-metre grid space built in the ALLCOORD program. The net result, then, is that REGISTER writes the test site portion of the overall classified image into the 80-metre grid, using the transformation just created.

```
:HELLO CARSON,ALASKA.IDIMS
:RUN IDIMS.PUB;LIB=P

   SMSUS>LOAD

   SMSUS>REGISTER>BIGLAKE.REG.NEWCPS

   PLEASE SUPPLY PARAMETER VALUES FOR FUNCTION REGISTER:
   MAXTYPE:             CR
   MIPTS:               CR
   DIPTS:               CR
   NLOUT:1              244
   NSOUT:2              270
   NOOUT:               NO
   INTERPOL:            NN
   TMTXREC:             T3BLTMTX
   TMTXFILE:            T3BLTMTX.NDAKOTA.GIS

       T3BLTMTX       T3 17 OF 19 NEW CPS 31181 CCH
       (System prints out contents of TMTX record comment.)
```

Coefficients of T3BLTMTX are echoed on user terminal. They are, of course, the same coefficients listed from the TRNSFORM program.

END FUNCTION REGISTER

VI. Generating Output Products for Transmittal to ESRI

The first output product to be generated, once the REGISTER output image was viewed on the display and visually evaluated, was a line printer map which was overlaid on the ESRI-generated map of ESRI photointerpreted data.

```
BIGLAKE.REG.NEWCPS>LPMAP
```

---

1. NLOUT was calculated by finding the number of metres represented by the N/S direction of the study area/80-metre grid space, and dividing by 80.

2. NSOUT was calculated by finding the number of metres represented by the E/W direction of the study area/80-metre grid space, and dividing by 80.

```
PLEASE SUPPLY PARAMETER VALUES FOR FUNCTION LPMAP:
CHARS:        ' WW                          '        (Assigns blanks to all but water)
STEPSZ:       CR
DEVICE:       CR
COMMENT:      'BIG LAKE AREA    INTRISCA    REGISTER OUTPUT    NEW CPS    +
              ESRI GIS INTEGRATION'
COPIES:       2

END FUNCTION LPMAP
```

(One copy of the LP map was generated for ESRI and one for Ames.)

The REGISTER output line printer map was overlaid on the ESRI map and the fit was satisfactory.

The second output product to be generated was the tape via which the georeferenced data was to be transmitted to ESRI.

```
BIGLAKE.REG.NEWCPS>TRANSFER(FILENO=1 SPECTYPE=SAME REALFORM=HP)

END FUNCTION TRANSFER
```

The georeferenced image was then stored on the IDIMS system on a Store Tape, on the ALASKA.IDIMS account, for future reference. The Transfer tape and one of the LP maps were transmitted to ESRI on March 11, 1981. A list of class identifications for the Susitna scene was also transmitted (Table 38).

CCH/c

Big Lake (Alaska) GIS Integration

CLASS IDENTIFICATION

Class Number	Color	Cover Type
1	Aqua	Sedimented water
2	Medium blue	Clear water
3	Brown	Shrub/moss bog
4	Brown	Black spruce bog
5	Yellow	Grass
6	Yellow	Shrub
7	Dark green	Conifer
8	Olive	Mixed forest
9	Light green	Deciduous
10	Black	Barren
11	Dark grey	Alpine tundra
12	Grey	Glacier
13	White	Snow
14	White	Cloud
15	Black	Shadow
16	Purple	Commercial/industrial
17	Violet	Transportation facilities
18	Reddish brown	High-density residential
19	Red	Low-density residential
20	Purple	Central business district
21	Purple	Commercial
22	Black	Background

Image on tape: 244 records, each 270 bytes long
single band
one file

Table 38

Georeferencing a Portion of the Anchorage Image

INTRISCA PROJECT

Alaska/ESRI GIS Integration Effort

Charlotte Carson-Henry

May 1981

HILLSIDE TEST SITE

I. Data Preparation

Evaluation of the classified data set for the Eastern/Anchorage test site demonstrated that control points could not be selected, with any reliability, from the classified data set. The raw data had not been deskewed/rotated prior to classification; the classified data set was instead submitted to the 360/TSS ROTATE program following the completion of stratification. Parameter values affecting rotation (HSKEW and VSKEW) were obtained for that ROTATE job by running SKEW on the 360/TSS.

For purposes of the GIS integration effort, control points were required to be selected from the raw data, rotated to exactly overlay the classified data. Since the ROTATE program operates only on single-band data, the DESKEW program on the 360/TSS was utilized to generate the required rotation of the raw data. DESKEW and ROTATE utilize the same algorithm (RECTFY3) as well as the parameters HSKEW and VSKEW; the parameter values HSKEW=.468 and VSKEW=.257 were used in DESKEW as they had been for the ROTATE on the classified data. The DESKEW output was in EDITOR-compatible format, and was reformatted using the 360/TSS program LL so that it could be read by IDIMS. The output tape was then entered on IDIMS and subsequently used for control point selection.

During control point selection, it came to light that although the same algorithm had operated on both the raw and classified data sets, using the same parameters for skew to determine degree of rotation, the newly-rotated raw data did not overlay the rotated classified data. Rotated output on the two data sets was, in fact, markedly different in size. Investigation identified the cause: when DESKEW was run on the raw data, the full CCT was required/used as input and the RECTFY3 algorithm calculated the centerpoint of the scene — around which to rotate. When ROTATE was run on the classified data, a full scene data set was neither needed nor available, so a subset was used as input; the RECTFY3 algorithm calculated the center point of that subset — around which to rotate. The center points of the two scenes were not, of course, in the same location.

Rather than incur the expense required to re-rotate one data set or the other, an attempt was made to transfer the control points from the raw data to the classified data by means of line printer maps of corresponding subsections from the two data sets. These maps were overlaid and local fits were attempted manually. The presence of cloud cover in the southwestern portion of the

Anchorage Peninsula, coupled with the absence of clear land use patterns in the central portion of the study area, prevented transferral of approximately half of the control points with any degree of confidence and an alternate approach was sought.

A NASA programmer provided the means for solving the problem. He used a hard copy of the RECTFY3 code and verified (by manual calculation) that the program had correctly computed the center point of each scene. He then created an EDITOR OCAL (oblique calibration) file using the alpha and beta values as computed by DESKEW/RECTFY3, and then used the Calculate Coordinates routines in EDITOR to transform raw data coordinates into DESKEW output coordinates. This enabled translation of the center point coordinates of the unrotated classified data into the rotated raw data space, which in turn allowed the manual computation of the difference between the coordinate systems of the two image spaces. The control points selected from the raw data were then manually translated into rotated classified data coordinates, for use in the registration to be performed. (See Figures 50 and 51 for an illustration of the problem.)

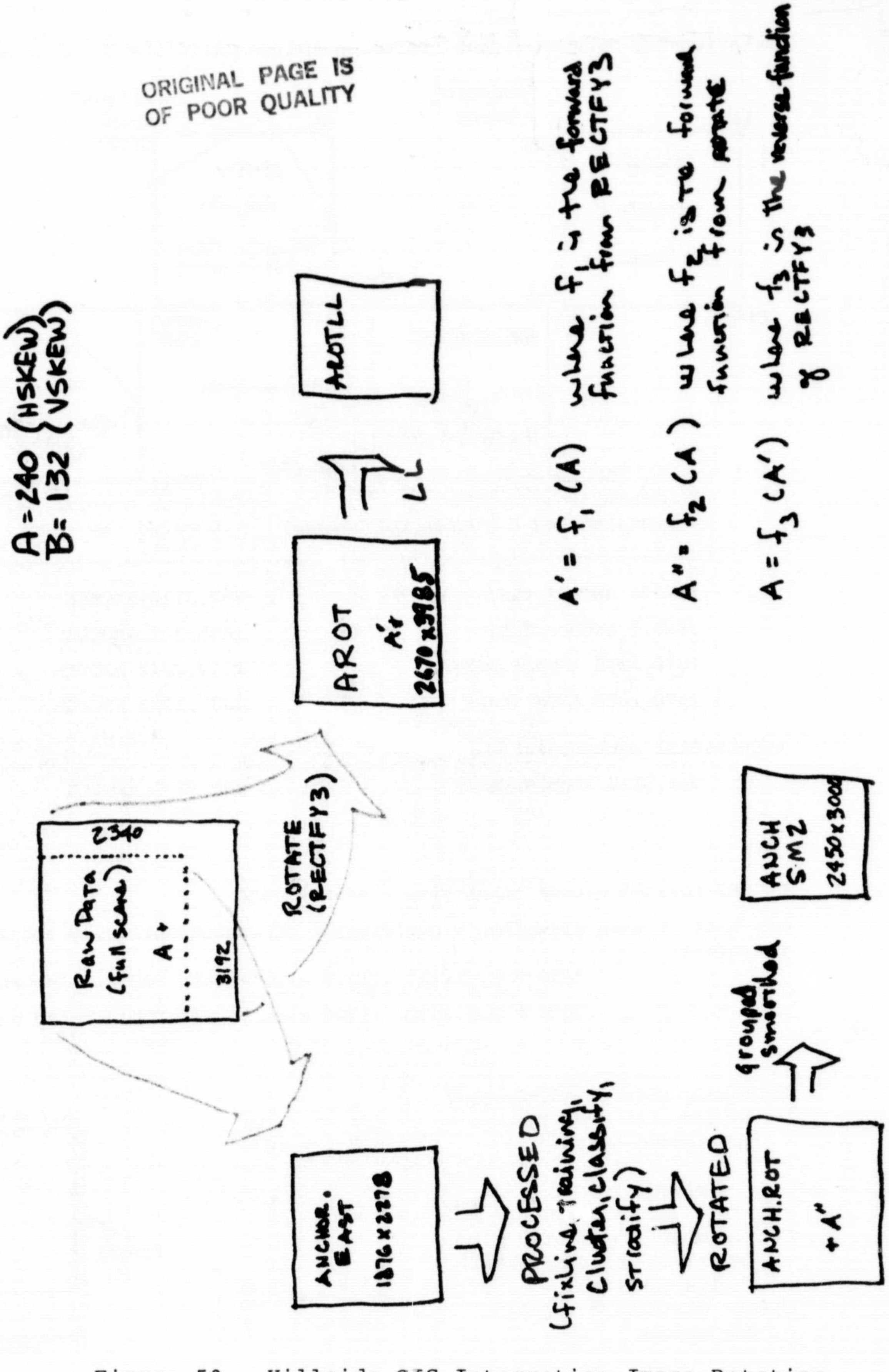
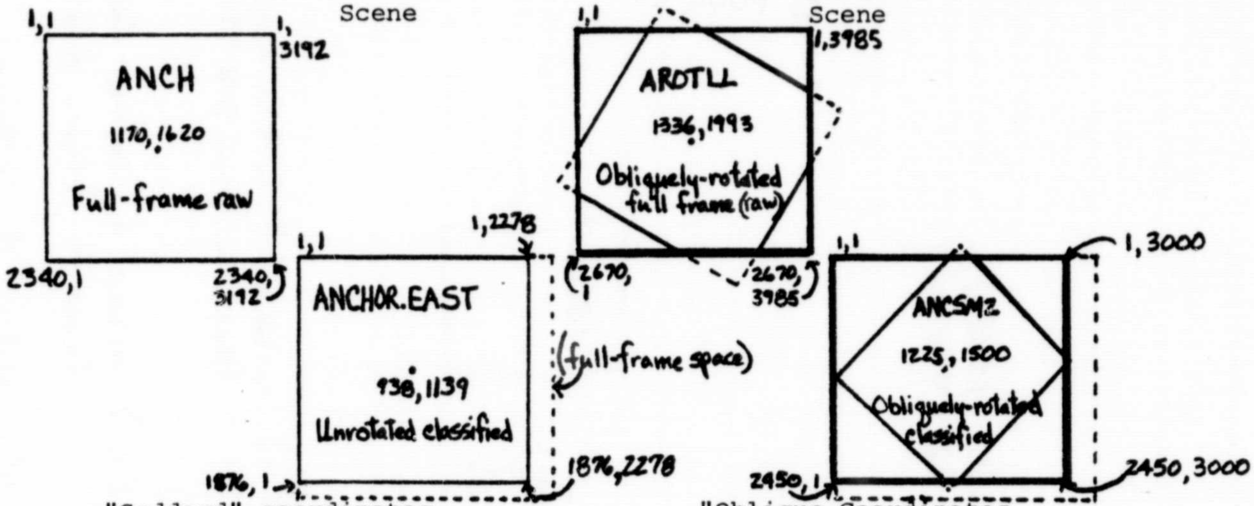


Figure 50. Hillside GIS Integration Image Rotation Process

KDM

Relationship between scenes, based on EDITOR Calculate Coordinates routine:

"Goddard" Scene   "Oblique" Scene



"Goddard" coordinates (Unrotated raw & classified scenes)

"Oblique Coordinates (Rotated raw scene)

1,2278 ANCHOR.EAST (clasd)	=	337,3119 AROTLL
1876,1 ANCHOR.EAST	=	1625,239 AROTLL
1876,2278 ANCHOR.EAST	=	2212,2242 AROTLL
1170,1620 ANCH (raw)	=	1336,1993 AROTLL

ANCHOR.EAST centerpoint:

938,1139 ANCHOR.EAST	=	980,1679 AROTLL

ANCSM2 rotated output image size = 2450 x 3000

One-half of each dimension = centerpoint of output obliquely-rotated image, therefore:

2450 ÷ 2 = 1225 (1225 also equals YOUTH value on RECTFY3)

3000 ÷ 2 = 1500 (1500 also equals XOUTH value on RECTFY3)

	(N)	(W)
Obliquely-rotated ANCHOR.EAST centerpoint coordinates, in full-frame space	980	1679
MINUS		
Centerpoint coordinates of ANCSM2 (classified data), in its own space	- 1225	- 1500
YIELDS difference between two spaces	- 245	179

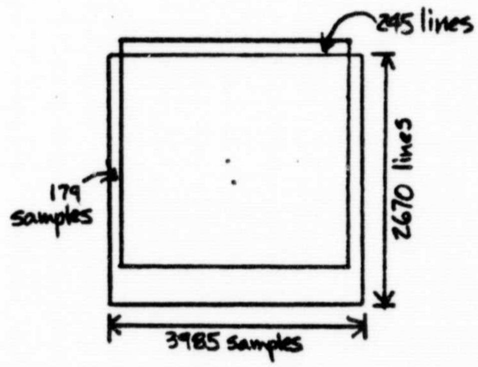


Figure 51. Hillside GIS Integration Image Relationships

II. Control Point Selection

Control points were selected using the IDIMS display and a 1:63,360 scale quad sheet map on which the Hillside study area had been located using UTM coordinates supplied by ESRI as described previously. Ten points were located on the raw data and on the map, and their sample/line coordinates were noted for creation of a text file. The HP 3000 Text Editor was then used to create that text file, containing control point names and the noted coordinates for those points, after the points had been translated manually into the coordinate system of the classified rotated imagery as discussed in Section I of this portion of the paper.

```
:HELLO CARSON,NDAKOTA.GIS
welcome message
:EDITOR
welcome message
/ADD
```

NOTE: NOT PART OF TEXT FILE:

				Description	Quality	Move
1	HS1	1442	1687	Lake Hideaway	Fair (Map)	??
2	HS2	1440	1685	Intersect. O'Malley & Birch	Excel.	none
3	HS3	1384	1629	Sm. lake N. of S.Fork	OK	NE 1
4	HS4	1336	1581	Lake Otis	OK	S 1
5	HS5	1601	1846	McHugh Creek & Turnagain Arm	Fair	?
6	HS6	1526	1771	Junction 2 forks Rabbit Creek	Good	?
7	HS7	1672	1917	Gull Rock #1, Kenai Peninsula	Good	W 1
8	HS8	1801	2046	S. end landing strip, pipeline	Excel.	N 1 or none
9	HS9	1353	1598	Hood Lake, Anchorage	Good	none
10	HS10	1413	1658	Jewel Lake, S. shore	Excel.	NE 1
11	//					

```
/KEEP HSIMGCPS.NDAKOTA.GIS,UNN
/EXIT
:
```

The coordinates used above are the translated coordinates for the control points; the coordinates as recorded from the raw data were as follows:

Name	Sample #	Line #	Name	Sample #	Line #
HS1	1242	1442	HS6	1302	1526
HS2	1216	1440	HS7	1214	1672
HS3	1241	1384	HS8	1056	1801
HS4	1158	1336	HS9	1051	1353
HS5	1249	1601	HS10	1054	1413

These coordinates were translated into the values entered into the text file by subtracting 178 from the sample numbers and adding 245 to the line numbers, those being the numbers that represent the relationship between the raw image space and the classified image space, after both data sets were rotated as described in Section I of this portion of the paper. A brief description of the derivation of these two numbers is as follows:

Coordinates of center point of the obliquely-rotated subsection image, in obliquely-rotated full-frame space:	Line 980	Sample 1679
MINUS		
Coordinates of center point of the obliquely-rotated subsection image, in its own space:	- Line 1225	Sample 1500
	-245	179

III. Digitizing Control Points

The control points selected on the IDIMS screen and concurrently marked on the 1:63,360 maps (Anchorage A-8 and Seward D-8) were then digitized using the TALOS digitizer and the GES software on the HP 3000. Required by this program are: definition of a Geoblock (area within which digitizing will occur), definition of files, and menu registration. Control points were digitized as follows:

:RUN GES.PUB
welcome message
Prompts regarding terminal type, digitizer type, digitizing tolerance, and coordinate system in which digitizing information will be entered, then:

(Abbreviated prompts:)

Geoblock Directory File Name?	HSGEOBLK	
Prompt for Label Positions?	N	(Used w/ polygons only)
Six-character Geoblock Name?	HILSID	
Geoblock Dimensions:		
Lat/lon of lower left corner?	60 45 00 N 150 00 00 W	
Width, height (in minutes) ?	25,30	
Area File Capacity?	CR	
Tolerance?	CR	
Overlay Number ?	1	
New OVLY. Proceed?	Y	
OV Type?	P	(Point)

(Register Map routines)
For Seward D-8, used lower point of 60 50 00 N ; 150 00 00 W
Distance between upper and lower points: 10 minutes
(Upper Reg. Pt. — MAPREG2 — 61 00 00 N ; 150 00 00 W)

MAPREG3: 60 00 00 N ; 149 40 00 W
MAPREG4: 60 50 00 N ; 149 40 00 W
MAPREG5: 60 50 00 N ; 149 50 00 W
MAPREG6: 61 00 00 N ; 149 50 00 W

Tested points; registration looked to be within a maximum of 1-second error, which could be attributed to cursor placement during digitization. Defaulted out of Register Map routines.

Spark ENTER on menu.
Class ID? 1
Spark point; point ID? HS8
Spark point; point ID? HS7

Defaulted out of Enter mode, since additional control points on different map.

Mounted Anchorage A-8 quad sheet on digitizer bed, sparked Register Map.

(Register Map routines)
For Anchorage D-8, used lower point of 61 00 00 N ; 150 00 00 W
Distance between lower and upper points: 15 minutes
(Upper Reg. Pt. — MAPREG2 — 61 15 00 N ; 150 00 00 W)

Do you Desire a Higher Order Transform? Y
Begin with What Order? 1
Registration Point Interval (minutes) ? 10

MAPREG3: 61 15 00 N ; 149 50 00 W
MAPREG4: 61 15 00 N ; 149 40 00 W
MAPREG5: 61 00 00 N ; 149 40 00 W
MAPREG6: 61 00 00 N ; 149 50 00 W
MAPREG7: 61 10 00 N ; 149 45 00 W
MAPREG8: 61 05 00 N ; 149 45 00 W

Since the control points covered a large portion of this map, registration points were more widely disbursed to ensure a better fit. Map registration seemed to be acceptable, with a maximum of one-second errors when points were tested.

Defaulted out of the Register Map routines.

Spark ENTER on menu.
Class ID? 1
Spark point; point ID? HS3
" " HS1
" " HS2
" " HS4
" " HS9
" " HS10
" " HS6
" " HS5

Spark DEFAULT on menu to escape Enter mode.

Since all points have now been digitized, STOP is sparked on the menu to terminate the GES program.

The control points here digitized were subsequently transformed into the 80-metre grid space built with ALLCOORD, and that transformation was used by the IDIMS REGISTER function in creating the georeferenced output image. These processes will be illustrated in the next few sections of the paper.

III. Construction of 80-metre UTM grid

The program ALLCOORD on the HP 3000 was used to create a grid of 80-metre cells in a UTM base. The digitized control points were subsequently transformed into this grid space coordinate system.

```
:HELLO CARSON,NDAKOTA.GIS
welcome message
:RUN ALLCOORD.UTILS.IDIMS
welcome message

(Abbreviated prompts:)

Line printer listing of output desired?       Y
Input coordinates are in the form of?         P    (GES control point file)
Name of Geoblock File?                        HSGEOBLK
Name of desired Geoblock?                     HILSID
Class ID?  (CR for all)                       CR
Output text file desired?                     Y
Name of file to receive output?               HLSID80M
Capacity limit?                               CR
Store coordinates as?                         G    (Grid option)
State Plane Zone?  (CR to omit)               CR
UTM coordinates of grid origin?               345000,6782000
Dimension of grid cells, in metres?           80

         XMIN=     -62.     YMIN=     -65.
         XMAX=     137.     YMAX=     364.

         FINISHED; 10 POINTS PROCESSED.

END OF PROGRAM
:
```

TUE, MAY 5, 1981, 1:00 PM

```
                   GEOBLOCK FILE   HSGEOBLK
                        GEOBLOCK   HILSID
                       CLASS ID:   ALL

                OUTPUT TEXT FILE   HLSID80M
           COORDINATES STORED AS   UTM GRID
 UTM COORDINATES OF GRID ORIGIN     345000.   6782000.
      SIZE OF GRID CELL IN METERS       80.
                        UTM ZONE    6
```

	COORDINATE:		TOTAL SECONDS		UTM (METERS)	
HS8	60 52'51"N	149 56'48"W	-539808	219171	340064.	6752899.
HS7	60 58' 6"N	149 46' 1"W	-539161	219486	350224.	6762204.
HS3	61 9'41"N	149 44'40"W	-539080	220181	352343.	6783669.
HS1	61 7'23"N	149 44'27"W	-539067	220043	352354.	6779387.
HS2	61 7'25"N	149 46'20"W	-539180	220045	350667.	6779510.
HS4	61 11'28"N	149 50'35"W	-539436	220288	347176.	6787206.
HS9	61 10'47"N	149 58' 1"W	-539881	220247	340468.	6786216.
HS10	61 8'20"N	149 57'48"W	-539868	220100	340460.	6781666.
HS6	61 4' 1"N	149 40' 9"W	-538809	219841	355960.	6772991.
HS5	61 0'59"N	149 43'42"W	-539022	219659	352542.	6767494.

ALLCOORD output

Table 39. Hillside ALLCOORD Listing

IV. Computation of Transformation

In order to translate image control point coordinates into 80-metre-grid-relative coordinates, a transformation between the two spaces was constructed using the HP 3000 program TRNSFORM.

:RUN TRNSFORM.UTILS.IDIMS
welcome message

(Abbreviated prompts:)

Instructions?	N
Origin for Source control points?	3 (Text file)
X,Y Biases?	0,0
Name of Source text file?	HLSID80M (80-metre grid text file
Origin for Destination control points?	3 (Text file)
X,Y Biases?	0,0
Name of text file?	HSIMGCPS (Image CP coordinates)
Print matching points on LP?	Y
Enter name of TRNSMTX file?	T3HILSID
FOPEN ERR, etc.	B (Build option)
Capacity?	100 (100-record capacity for file)
Desired filename, or CR for T3HILSID?	CR

First- and second-order fits were computed. One point emerged with a point residual exceeding 1.0; reference to notes taken during control point selection revealed that the point in question was noted as having the potential for a move one pixel to the south. The Text Editor file containing image control point coordinates was accessed and modified so that the coordinates for control point HS4 were effectively moved south by one pixel, from 1336,1581 to 1336,1582. The first-order transformation was again computed, and residual errors improved throughout. No points were deleted from the transformation, and no residual error exceeded 0.9 in either the X or Y direction. The first-order transformation was used.

RESIDUAL MEANS: .333203 .426270

NUMBER	A(N)	B(N)
1	1653.02	947.037
2	1.07534	.253392 E-01
3	-.211641 E-01	1.26854

Do you wish to alter points?	N
Do you wish this to be the highest order transform?	Y
Enter name of TRNSMTX record?	T3HILSID
Enter description of record?	Control X, followed by: 80M GRD TO ANCSM2 5 8 81 CCH
Do you wish the inverse transformation?	N

END OF PROGRAM
:

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POINT	SX	SY	DX	DY	TX	TY	RX	RY
1 HS8	-62	364	878	2046	878	2045	.0	.5
2 HS7	65	247	1036	1917	1036	1918	-.1	-.7
3 HS3	92	-21	1063	1629	1063	1629	.1	.4
4 HS1	92	33	1064	1687	1064	1686	-.5	.6
5 HS2	71	31	1038	1685	1038	1685	.3	.0
6 HS4	27	-65	980	1582	980	1582	.1	-.5
7 HS9	-57	-53	873	1598	874	1598	-.8	.5
8 HS10	-57	4	876	1658	875	1659	.9	-.7
9 HS6	137	113	1124	1771	1124	1771	.3	-.2
10 HS5	94	181	1071	1846	1071	1846	-.2	-.0

RESIDUAL MEANS = .333203 .426270

Final Hillside TRNSFORM Listing

Table 40. Hillside Transformation

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:RELEASE T3HILSID
:BYE

The RELEASE command allows the transformation matrix file to be accessed from other accounts or log-on groups. REGISTER is an IDIMS function and must access the transmatrix file from an IDIMS account log-on group.

V. Creating Georeferenced Classified Image

The final step in georeferencing the rotated classified image to an 80-metre UTM map base involved the use of the IDIMS function REGISTER. While the function can be run in several different modes, in this instance it accessed the transmatrix file and record created in the previous step (TRNSFORM) and then used the coefficients of the transformation to create and fill an output image space which conformed to the UTM map base and which was comprised of 80-metre square pixels. This final image contained only that portion of the entire classified image that conformed to the placement and size of the UTM grid created in ALLCOORD. The NLOUT and NSOUT parameters in REGISTER specify the number of lines and samples in this output image, and were manually computed in the following manner:

NLOUT= the number of metres represented by the North/South direction of the study area/80-metre grid space (in UTM coordinates), divided by the grid cell size of 80 metres.

NSOUT= the number of metres represented by the East/West direction of the study area/80-metre grid space (in UTM coordinates), divided by the grid cell size of 80 metres.

Therefore, with grid corners of

Upper left:	345000 E	6782000 N
Lower right:	354500 E	6772000 N

the calculation becomes

$$\begin{array}{r} 6782000\ N \\ -\ 6772000\ N \\ \hline 10000\ N \end{array} \qquad \begin{array}{r} 354500\ E \\ -\ 345000\ E \\ \hline 9500\ E \end{array}$$

$10000 \div 80 = 125$ (Northing/lines)

$9500 \div 80 = 118.8 = 119$ (Easting/samples)

Each of these numbers is then translated into the next highest even number, yielding 126 lines and 120 samples.

Therefore, NLOUT=126 and NSOUT=120 when running REGISTER.

```
:HELLO CARSON,ALASKA.IDIMS
:RUN IDIMS.PUB;LIB=P

    ANCSM2>LOAD                    (Brings classified, rotated image on-line)

    ANCSM2>REGISTER>HILLSIDE.REG
    PLEASE SUPPLY PARAMETER VALUES FOR FUNCTION REGISTER:
    MAXTYPE:            CR      (These first three parameters not used when
    MIPTS:              CR       REGISTER accesses an existing transformation.)
    DIPTS:              CR
    NLOUT:              126
    NSOUT:              120
    NOOUT:              NO      (Output image wanted)
    INTERPOL:           NN      (Nearest-neighbor)
    TMTXREC:            T3HILSID
    TMTXFILE:           T3HILSID.NDAKOTA.GIS

    T3HILSID      80M GRD TO ANCSM2 5 8 81 CCH

    (System prints out transformation matrix record comment.)
```

The system will then print the coefficients from the transformation matrix file and record, on the user's terminal, and proceed to create the 126 x 120 output georeferenced image. The coefficients, of course, are identical with those listed during the running of the TRNSFORM program.

END FUNCTION REGISTER

VI. Verification of Registration and Preparation for Transmittal

In order to assess the accuracy of the registration, a line printer map of the georeferenced image was generated and compared to maps of corresponding portions of the raw data using Bands 4 and 7, which were generated previously. A second copy of the LP map was generated for transmittal, with the tape containing the georeferenced image, to ESRI.

```
    HILLSIDE.REG>LPMAP
    PLEASE SUPPLY PARAMETER VALUES FOR FUNCTION LPMAP:
    CHARS:        ' WW                              ' (Assigning blanks to all but water)
    STEPSZ:       CR
    DEVICE:       CR
    COMMENT:      'HILLSIDE AREA    INTRISCA    REGISTER OUTPUT    ESRI GIS +
                  INTEGRATION'
    COPIES:       2

    END FUNCTION LPMAP
```

A transfer tape was then written for transmittal of the image to ESRI.

```
HILLSIDE.REG>TRANSFER
PLEASE SUPPLY PARAMETER VALUES FOR FUNCTION TRANSFER:
FILENO:      1
SPECTYPE:    CR     (Same)
REALFORM:    CR     (HP)

END FUNCTION TRANSFER
```

Following completion of the transfer, the REGISTER output image was written to an IDIMS Store Tape, on the ALASKA.IDIMS account, for future reference.

A cover letter was prepared and transmitted to ESRI along with the transfer tape, one copy of the line printer map, and a class identification list (Table 41) corresponding to the classes in the Anchorage/ Eastern scene. The materials were sent to Russ Michel of ESRI on May 12, 1981.

5/13/81

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Table 41

Hillside (Anchorage, Alaska) GIS Integration

CLASS IDENTIFICATION

Cover Type	Class Number(s)	Color
Sedimented water	1	Aqua
Clear water	2	Medium blue
Shrub/moss bog	3	Brown
Black spruce bog	4	Brown
Grass	5, 27	Yellow
Shrub	6	Yellow
Conifer	7	Dark green
Mixed forest	8	Olive
Deciduous	9	Light green
Barren / mud	10, 25	Black
Alpine tundra	11	Dark grey
Glacier	12	Grey
Snow / ice	13	White
Cloud	14	White
Shadow	15	Black
Commercial / industrial	16, 17	Purple
High-density residential	18	Reddish brown
Low-density residential	19	Red
Hay / growing crops	23	Peach
Fallow agriculture	24	Tan
Shrub/grass tundra	26	Yellow

NOTE: There are no classes 20-22; those class numbers were used in the Susitna scene.